Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

OCTOBER, 1949 VOL. 5, NO. 10

Low Footage Cost
OF APPLYING NO-OX-ID PROTECTION
Achieved with This Fast-Moving Equipment

Because of the speed with which the traveling machine applies NO-OX-ID materials to pipe lines, the footage cost of NO-OX-ID protection is substantially reduced.

The compact, self-propelled unit rides the pipe and moves at a rapid rate, applying both coating and wrapper simultaneously, without the lost motions incident to manual applications. The pipe is cradled into the ditch immediately behind the coating machine. Illustration shows the unit making a hot application of NO-OX-ID 6X and wrapping the pipe with No. 7 NO-OX-IDized reinforced asbestos wrapper.

NO-OX-ID coatings contain chemical inhibitors, bond firmly, seal out all rust-forming moisture. Wrappers, also chemically impregnated and water repellent, aid in maintaining the coating's firm bond, reduce abrasion and soil attachment. All NO-OX-ID materials are nontoxic, cause no aggravating skin reactions.

"PIPING HOT," a new 16 mm sound movie in color on the use of hot-applied NO-OX-IDs by stationary machine, is available to companies, engineering clubs, or technical societies. Write for booking.

Dearborn
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THE LEADER IN RUST PREVENTIVES AND BOILER WATER TREATMENT

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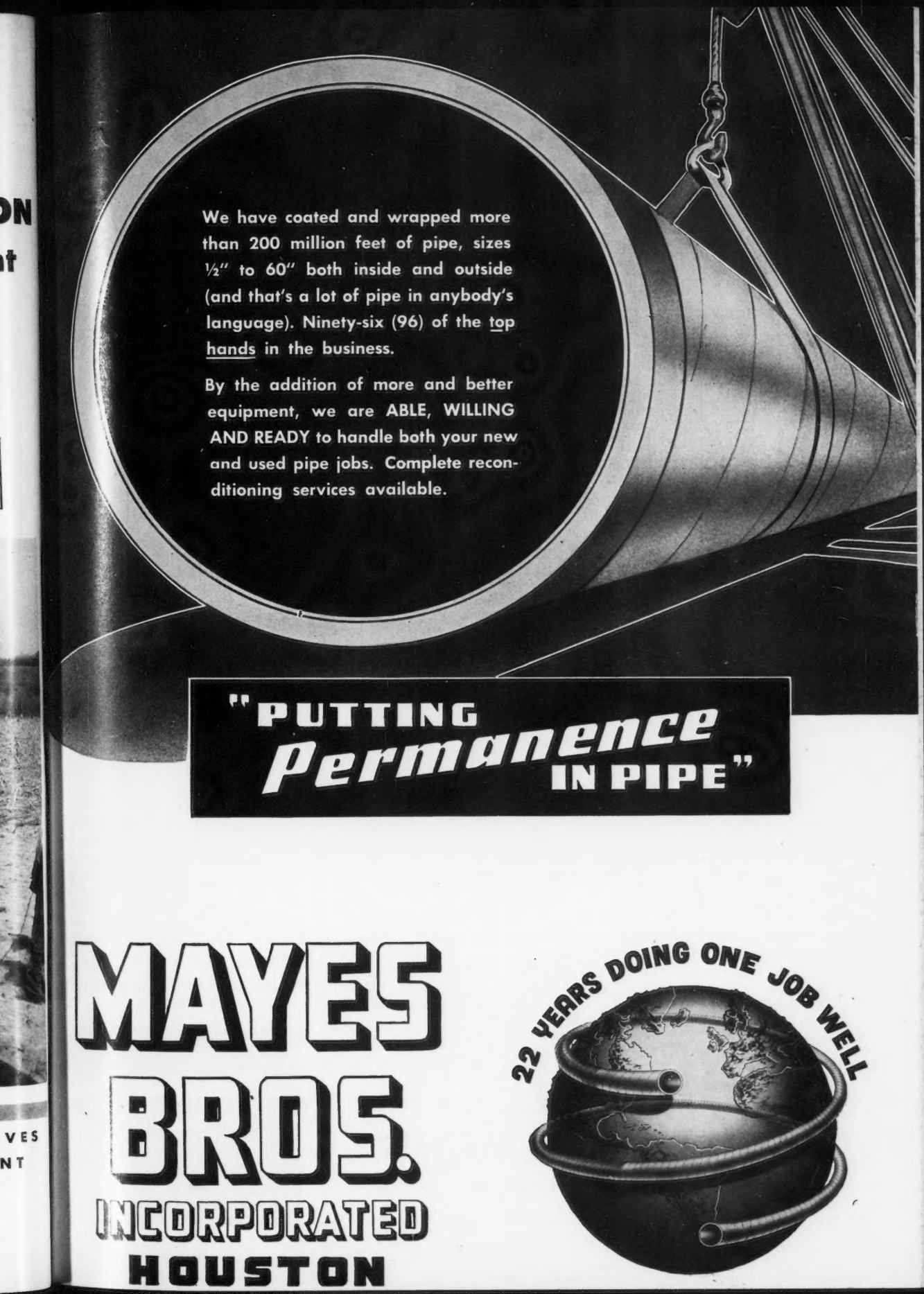
We have coated and wrapped more than 200 million feet of pipe, sizes ½" to 60" both inside and outside (and that's a lot of pipe in anybody's language). Ninety-six (96) of the top hands in the business.
By the addition of more and better equipment, we are ABLE, WILLING AND READY to handle both your new and used pipe jobs. Complete reconditioning services available.
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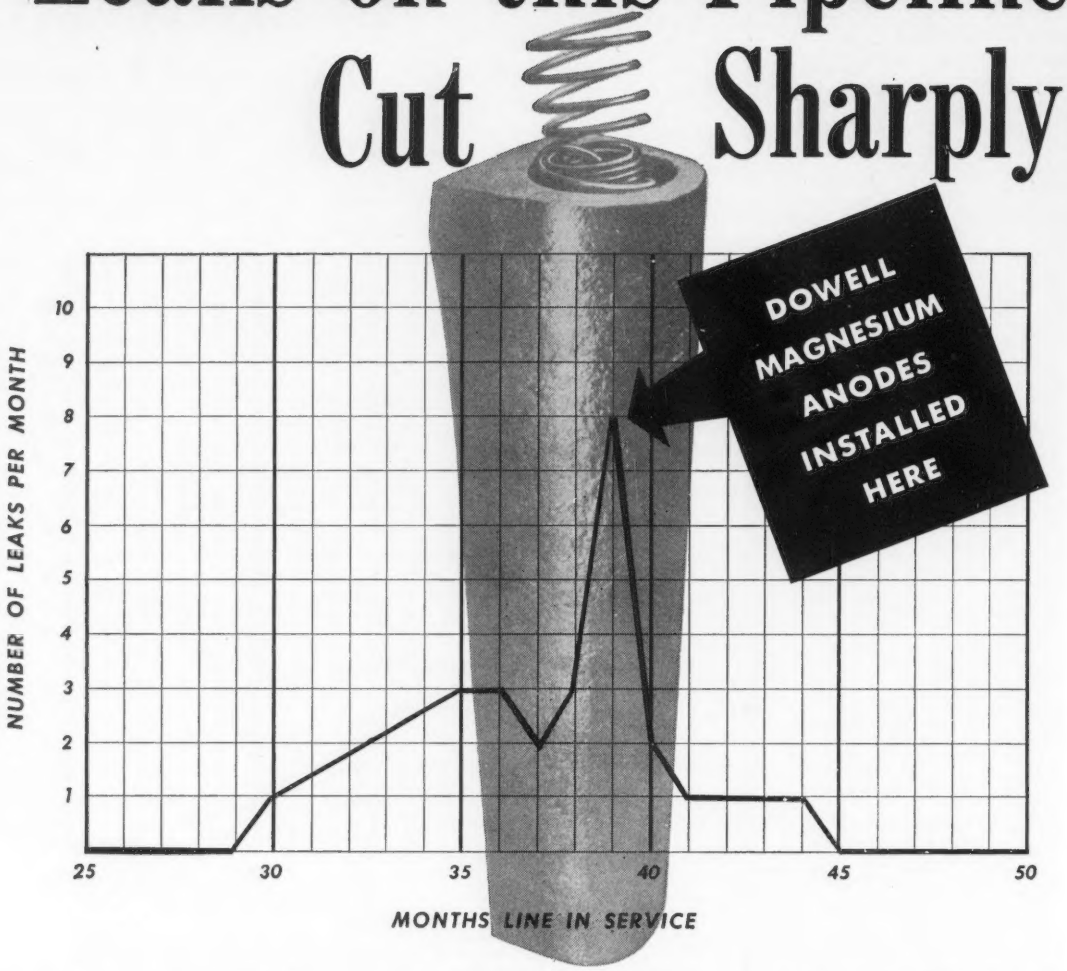
22 YEARS DOING ONE JOB WELL

Leaks on this Pipeline Cut Sharply



The graph above shows the dramatic reduction in leak rate that occurred when Dowell magnesium anodes were installed on a 33 mile 8 inch asphalt covered pipe line. This installation saved thousands of dollars in maintenance costs alone, as well as extending indefinitely the time when the line would have to be reconditioned or replaced.

This is an example of the savings that can result when Dowell anodes are used to control corrosion on underground pipelines. The degree of protection afforded will depend upon soil conditions encountered and the number of anodes used. Easily and economically installed on existing pipe lines, Dowell magnesium anodes require no external power and cut maintenance costs to a minimum. Also, Dowell anodes are alloyed to specifications designed for maximum anode efficiency and long life.

A subsidiary of The Dow Chemical Company—pioneer in the use of magnesium for cathodic protection—Dowell offers the technical know-how and extensive research facilities which make it the logical source for magnesium anodes for corrosion control. Write directly to Tulsa for additional information.

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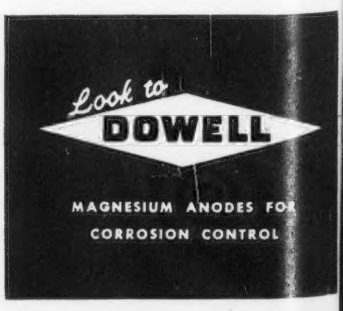

THIS MONTH'S COVER—The Mississippi River tug "Alton Zephyr" is shown after application of two aluminum anti-corrosion primer coats, five coats of air-drying vinyl-base material and a flat anti-abrasion and corrosion topcoat. This sprayed-on application withstands abrasive action of silt-laden water which often "sands" hulls to bare metal, according to Minnesota Mining and Manufacturing Co., makers of the coatings.

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devoted entirely to

Research and Control

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VOL. 5 OCTOBER, 1949 NO. 10

CONTENTS

	Page
Directory of NACE Regional and Sectional Officers	iv
Technical Committee Activities—Technical Information on Corrosion at Elevated Temperatures Sought	xi

TECHNICAL SECTION

The Use of Selenium Rectifiers as One-Way Valves In Electrolysis Drainage Wires *By W. D. Connon*	315
Corrosion Resistance of Commercially Pure Titanium *By G. E. Hutchinson and P. H. Permar* Discussion: By Fred W. Schmitz, Paul Gegner, Page 324; Dr. Mars Fontana, F. T. Wood, Jr., Tom R. Watson, B. B. Morton, Page 325.	319
The Study of Corrosion in the Colleges *By Hugh J. McDonald*	326
Electrochemical Behavior of Zinc and Steel in Aqueous Media *By H. B. Hoxeng and C. F. Prutton* Discussion: F. A. Prange, Page 338.	330
Deterioration of Steel Sheet Pile Grains at Palm Beach, Florida *By Culbertson W. Ross*	339
Technical Factors in Testing Pipe Line Coatings *By D. E. Stearns, M. W. Belson and R. H. Lee*	342
A Note on the Effect of Variations of Exposed Area On Solution Potential and Corrosion Rate of Low Carbon Steel *By J. M. Bialosky* Discussion: J. Preston Engle, Page 349.	346

DISCUSSIONS

Corrosion of Telephone Outside Plant Material: *C. J. Couy*	350
The Pulse Polarizer in Corrosion Technology: *F. L. LaQue, J. M. Bialosky*	350
Engineering Aspects of Cathodic Protection as Applied to Pipe Lines: *W. P. Noser*	351
An Investigation of Structural Steel Shop Coat Priming Paint: *Dr. H. F. Haase, I. E. Boberg, E. W. Wallace, S. M. Gleser*	352
Why Metals Corrode: *Norman Hackerman, Lyle R. Sheppard, W. F. Gross*	352
Topic of the Month: High Speed Stress, Corrosion Tester	354

NACE NEWS SECTION

North East Region News	1
North Central Region News	1
South Central Region News	1
Western Region News	2
Details Given About Exhibit Space at St. Louis	2
Canadian Council Joins Inter-Society Committee	2
1950 Conference Local Committees Organized	3
NACE New Members and Address Changes	3
14 Papers on Corrosion at Electrochemical Meeting	4
ASM Program Items of Corrosion Interest	4
British Institute to Hold Corrosion Session	4
New Products—Materials, Service, Literature	6

CORROSION ABSTRACT SECTION

	Page		Page
Atmospheric	14	Inhibitors	24
Bearing	14	Inspection	25
Cathodic Protection	16	Metal Failure	25
Chemical	18	Refinery	26
Coatings	20	Surface Preparation	26
Construction Material	23		

Index to Advertisers 27

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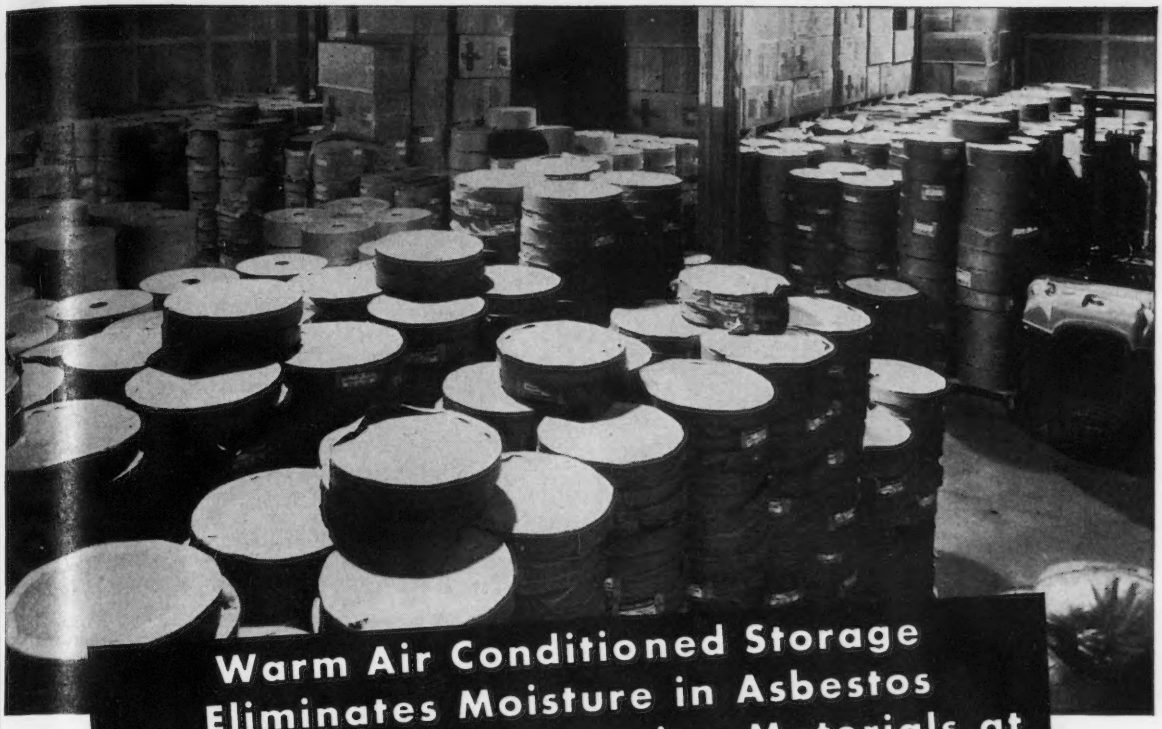

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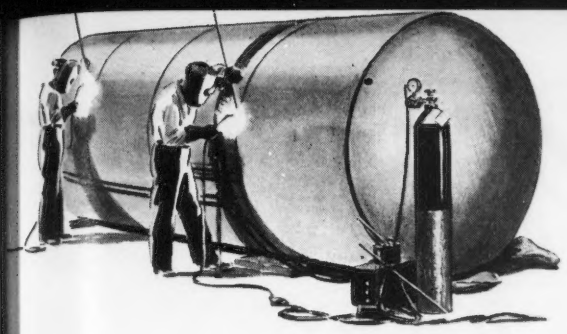

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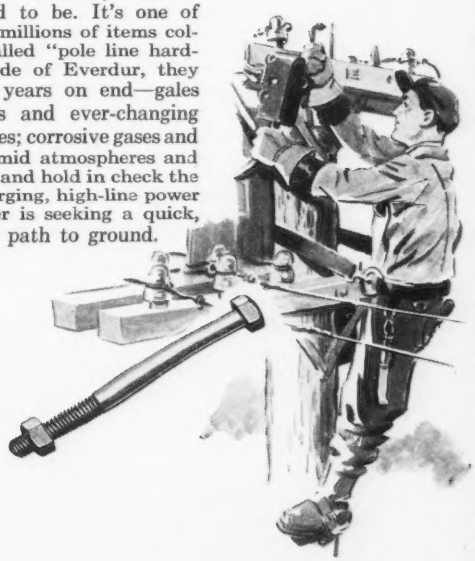

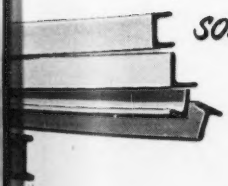

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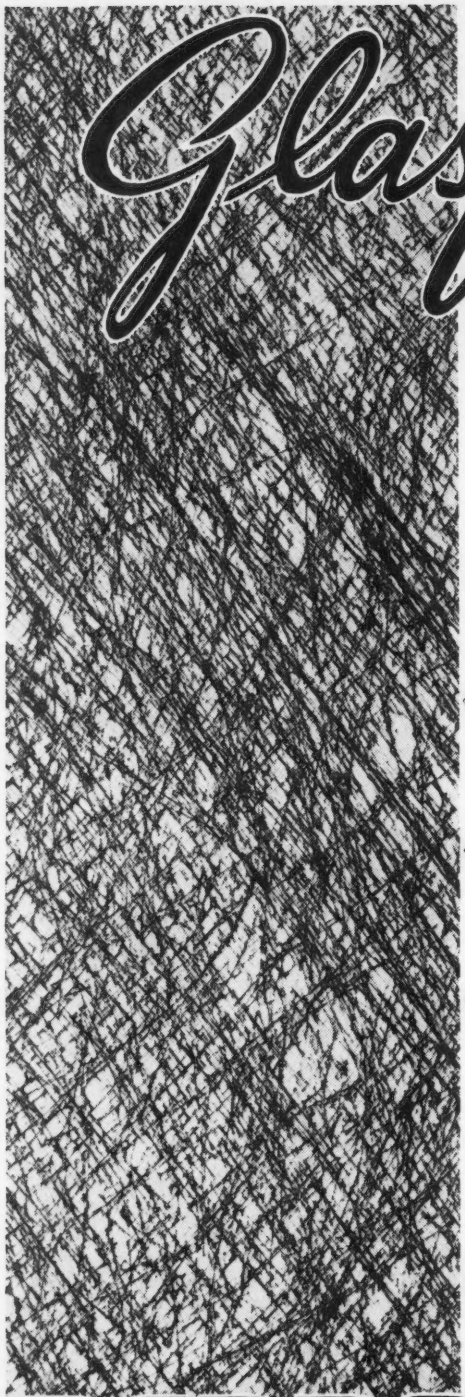

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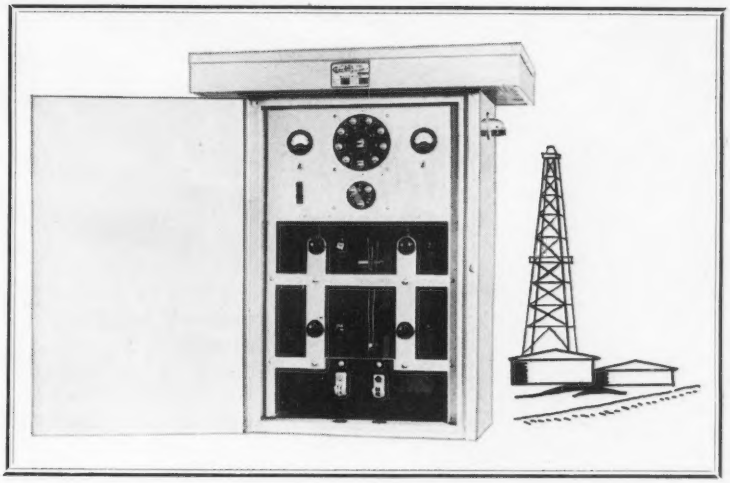

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Technical Information on Corrosion At Elevated Temperatures Sought

By M. A. SCHEIL*

TWO MEETINGS have been held with the membership of TP No. 7 and a program has been laid out to cover the scope of this Committee's activities.

At the first meeting it was decided that the cooperative work on corrosion problems encountered at elevated temperatures would be limited to temperatures above 400° F. It was agreed that the first subject on which to begin work would be carburization and decarburization during service at elevated temperature. A questionnaire form was made available to members of the commitee, and they were asked to distribute this within their own organization as well as others so that information could be had which would deal with the severity of the problem.

After several months of solicitation the results of the questionnaire form were rather disappointing. In general, some of the committee believed that the questionnaire was too comprehensive and that answering the questionnaire in full would entail revealing trade secrets. Others believed that the committee needed the questionnaire information before any study could be started to decide whether carburization or decarburization were of sufficient importance to warrant the committee setting up a program.

Results from the circulation of the questionnaire form have prompted the committee to defer attempts in solving specific problems of high temperature corrosion and instead to compile and clarify the high temperature corrosion data which is of great importance.

The committee is now considering the publication of a pamphlet which will be used as a source of information on the corrosion properties of about 25 materials in various environments above 400° F. Unpublished data will be obtained by means of a questionnaire and from the files of the membership of TP No. 7 acting as a nucleus.

A venture of this type will be successful only if this subcommittee can obtain the full cooperation of the membership of NACE. Many members have undoubtedly important information in their technical files regarding investigations of corrosion at elevated temperature. It is the desire of this subcommittee to have the members correspond freely on such data with the secretary, Mr. J. J. Heger, Carnegie Illinois Steel Corp., Frick Building, Pittsburgh, Pennsylvania.

* Chairman, TP-7, on Materials for Use at High Temperatures.

TECHNICAL PAPERS PROCEDURE

All papers submitted for publication in CORROSION are reviewed by the Editorial Review Committee, or specialists selected by that committee to review the papers. Suggestions of reviewers as to desirable additions or revisions are submitted to the author, who is given the opportunity to make the suggested changes. The paper in final form is accepted or rejected according to the judgment of the committee and the Editor of CORROSION. When the author can substantiate his viewpoint and prefers not to follow the suggestions of the reviewer and the overall paper merits publication, the author's wishes are followed.

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is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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The Use of Selenium Rectifiers As One-Way Valves In Electrolysis Drainage Wires*

By W. D. CONNON

THE USE OF a bond wire between the negative bus of a trolley substation and underground plant, such as a lead sheath telephone cable, to prevent anodic corrosion of the underground structure, has been recognized practice for many years.

With a single substation and track system, the potentials of underground structures near the substation are positive to the negative bus, since the current delivered to the tracks by trolleys at distant points divides among the tracks, the earth in which they are imbedded, and paralleling metallic structures in the ground, and returns to the negative bus or substation generators through the rails near the substation and the substation ground. Under these conditions, a bond wire between the negative bus and the underground cable always will carry current to the bus and provide protection to the cable.

W. D. CONNON

Since 1943 Plant Engineer for The Bell Telephone Co. of Pa., Philadelphia, Mr. Connon is responsible for transmission maintenance, inductive coordination, protection, radio maintenance and electrolysis mitigation in suburban Philadelphia and Delaware. He is a graduate of the University of Maine and has been employed continuously since graduation by his present company.

However, when two or more substations are connected to the same track and trolley system, the potential between the negative bus and nearby underground plant, at one or more locations, may be reversed at times, and, if connected by a bond wire, large currents will be delivered to the underground plant and result in accelerated anodic corrosion. Such reversals depend upon the relative magnitudes of trolley-to-track potentials at the various substations (which may be minimized by careful regulation of substation voltages) distribution of trolley loads and method of operation. The most severe reactions take place when one of the substations is heavily loaded or is removed from service during light load periods. In the latter case, the negative bus of the non-operating substation simply becomes a part of the track return system and, therefore, is at a high positive potential with respect to earth and the negative bus of an adjacent operating substation.

In order to prevent this reversal of potential from delivering current through bond wires to underground telephone cables, three general methods have been used:

1. Arrangements have been made with the trolley company to have the substation attendant open a switch in the bond wire when the station is shut down.
2. A procedure similar to No. 1 except that the switch is operated automatically by generator potentials.
3. The use of a reversing switch in the bond wire which is controlled by the relative potentials between the negative bus and the cable plant.

Since reversals do occur even when a substation is not shut down, Method No. 3—the use of an electrolysis reversing switch—has been normal practice for many years and, in general, gives satisfactory results. However, under certain conditions involving very frequent operation of the switch, rapid reversals, comparatively long periods of low current drain and the presence of AC potentials in the ground network, reversing switches have some disadvantages from the standpoints of adjustment, operation and maintenance. For this reason, some experimental work has been done in the use of selenium stacks to control the direction of current flow in electrolysis bond wires. It is the purpose of this paper to describe the practical application of these units with the thought that even though most electrical engineers are familiar with the general theory of rectification in semiconducting materials such as copper oxide and selenium and their uses, comparatively little has been published regarding their application as control valves in electrolysis bond wires.

For those who may not be thoroughly familiar with the characteristics of electrolysis reversing switches and dry disk rectifiers, the following brief descriptions are given:

Reversing Switch

This consists of an assembly of relays and pro-

★A paper presented at the Fifth Annual Conference of The National Association of Corrosion Engineers at Cincinnati, Ohio, April 11-14, 1949.

tective fuses connected in series with a bond wire between two structures such as the negative bus of a DC trolley substation and an underground cable. When the bus is positive to the cable, the current flow is limited by the comparatively high resistance of a polarized relay. Then, when the potential between the two structures reverses and the cable becomes sufficiently positive to the bus to operate the polarized relay and in turn a power relay capable of handling large currents, current will flow to the bus from the cable and give the latter cathodic protection. The relays are maintained in the operated position by the potential drop in the switch. (This sometimes is supplemented by the additional potential drop in a section of the bond wire.)

From the above, it should be noted that:

1. A small amount of reverse current flows through the control relay and bond wire when the bus is positive to the cable.
2. A low resistance through the switch is maintained only while an appreciable amount of current is flowing. Therefore, at critical values of current there is a tendency for the control relays to chatter.
3. Because the polarized relay must be designed to operate on small DC potentials, it also is sensitive to low frequency AC potentials such as those due to 25-cycle ground currents associated with electrified railroads. When the latter potentials are sufficiently large, the relay armature will vibrate in unison with the AC current, unless suitable choke networks are provided.
4. The main relay contacts must be of low resistance in order not to introduce excessive resistance in the bond wire. Any excessive operation of these contacts due to chatter or vibration, as outlined in Items No. 2 and 3, will result in high contact resistance due to arcing.
5. Inherent difficulties with self-actuated switches have caused their general replacement with power operated relay switches which require an external power supply.

The Dry Disk Rectifier Valve

This consists of one or more stacks of selenium or copper oxide plates connected in parallel with each other and mounted in a box with protective equipment. These disks have the property of presenting a low resistance to current flowing from the cable plant to the substation and a high resistance to reverse currents and thus are similar in operation to the reversing switch. Their operating advantages compared to the switch are as follows:

1. There are no moving parts and, therefore, the problem of maintaining low contact resistance resulting from normal and excessive relay operation is eliminated.
2. AC potentials, if present, produce rectified DC which flows in the right direction to give added cathodic protection to the cable plant.
3. There is a smooth transition from the condition of large forward currents into the substation to the small reverse currents which flow when the bus becomes positive to the cable. This in turn should result in the smooth operation of two or more units connected between the same substation bus and different underground structures. With mechanical switches, erratic operation of the relays sometimes occurs because current drained from one structure lowers the voltage between the bus and other structures having mutual ground couplings.
4. There is a minimum of faulty operation. In general, the unit is good or bad and this can be determined by simple voltage and current measurements.
5. No external power is required for the operation of the valve. This feature is of especial value when it is necessary to make a manhole installation.

As might be expected, there also are disadvantages and limitations in the use of the dry disk rectifier valve. A brief discussion of them is given below:

1. The reverse potential rating of these units is rather low and if exceeded is likely to damage them beyond repair. In this respect, the selenium units rated at about 20 volts per plate are superior to the copper oxide units which are rated at 6 volts per plate and for this reason the selenium type has been used in Bell Telephone Company of Pennsylvania installations.
2. When a unit breaks down because of excessive current or voltage surges, it must be replaced. This is expensive compared to the renewal of relay contacts or springs which usually is all that is necessary in the mechanical switch.
3. The resistance of a dry disk rectifier has a negative characteristic; that is, the resistance becomes lower as the current is increased. At high values of current, the resistance is low, but at low values of current the effective resistance is comparatively high. Therefore, in the case of either a small or large drainage current, a large number of disks in parallel must be used to reduce the overall resistance of the bonding system to a satisfactory level, or to provide sufficient current carrying capacity.
4. All of the plates in a unit are connected in parallel and, therefore, if a single plate breaks down it shunts the other plates and the entire unit is rendered inoperative. It is believed individual plates are damaged due to the generation of heat by excessive current. If the plates are not very uniform in their electrical characteristics, uneven distribution of current will occur and individual units will fail even though the total rated current of the complete unit is not exceeded.
5. As indicated in Item 3 above, the relationship between resistance and current is non-linear in a dry disk rectifier. To conform with standard bonding theory and practice, based on fundamental electrical laws, the bond connection should have a linear resistance in order to maintain a low negative cable-to-earth potential regardless of the amount of current flowing in the bond wire. The departure from linearity in the rectifier tends to give insufficient drainage at low currents, with consequent exposure of the cable plant, and overdrainage at high currents. These undesirable characteristics may not be important in some situations. For example, if the forward voltage is fairly high for a large percentage of time, then small exposures which occur during the low voltage periods may be tolerated. Also, if the design involves a high internal resistance and/or a comparatively high bond resistance, the relative effect of the variable rectifier resistance may be small. In any case, however, it is evident that careful consideration should be

given to circuit constants and operating cycles in the design of each installation. Results can be predicted accurately by modifying standard bond design procedure to include the resistance of the rectifier at various assumed values of current.

It will be noted that most of the disadvantages listed above involve the design and manufacture of the units themselves and may be minimized by further research and development work. At the present time, Bell Telephone Company of Pennsylvania is using a unit which has 16 rectangular plates approximately 4½ inches x 6 inches in size, with terminals brought out to heavy copper bars at diagonally opposite corners. Tentative ratings have been given as 80 amperes continuous current in the forward direction and currents considerably greater than this for very short periods (because failure results from heating rather than voltage drop). The maximum safe reverse voltage is 20 volts.

Five installations of selenium rectifier stacks as one-way valves have been made in company territory and a brief description of each follows:

Case I

A trolley line terminates at this location and a heavy underground cable run parallels the tracks on the same street back to the trolley substation and extends beyond the trolley tracks into suburban territory. Radial currents exposed the cables in the area beyond the tracks and insulating joints were installed to block this current. However, this did not clear the exposure entirely because there still were radial earth currents picked up by the cables beyond the insulating joints which then dropped off again to bypass the insulating joints in their paths back to the substation. This condition was cleared by installing the rectifier plates of an old copper oxide rectifier across the joints poled so it blocked the radial currents coming out over the cables but presented only a low resistance to currents returning to the substation. This arrangement cleared the area formerly exposed. The delivery of current to the substation side of the insulating joints was not serious because the cables were excessively negative to ground at that location and the main problem there involved the prevention of cathodic failures.

The original rectifier units were placed in 1944 and failed in 1946. At that time, they were replaced with three 10-ampere selenium stacks. In December, 1948, these also were showing signs of deterioration and it is planned to replace them with a single 80-ampere unit.

Case II

At this location, the underground cables pass under an electrified railroad (25 cycle AC power) and both structures are influenced by a 600-volt DC high speed suburban trolley line. Conditions were such that when the cables were positive to earth, they also were positive to the railroad ground structure. However, reverse potentials were frequent and averaged about 50 percent of the total time. A bond was made between the cables and the ground structure and a bank of three 10-ampere selenium stacks in parallel was used to take care of the reverse potentials. AC potentials resulting from 25-cycle train operation provided additional drainage current which was helpful, although not ideal, because the train and trolley schedules were not the same. This installation was made in July, 1947, is still operating satisfactorily and no replacement of the units has been necessary to date.

Cases III and IV

These cases involve a large suburban territory served by a high speed DC trolley line and a large network of underground telephone cables. The trolley R/W is on private property on good stone ballast and in general passes through the outer edges of the built-up communities. The two substations supplying power to the system in this area are in isolated spots at some distance from the underground telephone plant, and have comparatively high resistance ground networks.

Routine electrolysis surveys over a period of years had indicated large exposed areas, but a comparatively low cable failure rate did not seem to warrant a large expenditure for remedial measures. However, in 1945, there was a sudden increase in the number of failures and it was decided to design and install bond wires to both substations.

After the removal of all incidental contacts between the underground cables and water pipes, standard tests and computations indicated maximum drainage currents in the order of 30 or 40 amperes and reverse potentials as high as 20 volts at both locations. Because these values were within the ratings of 80 amperes and 20 volts of a recently developed selenium stack, arrangements were made to use this type of unit in place of a mechanical reversing switch.

Both bonding systems were placed in operation in December, 1947, and initial results were encouraging. However, in January, 1948, a 13KV transmission line fell across the trolley line and both units were severely damaged and had to be replaced. About two months later, one of the units failed again. This time the trouble was associated with a trolley-to-rail fault. In order to minimize the effect of these transient conditions, a 1000 mf electrolytic condenser was connected across each unit on April 3, 1948. Since that time, there have been no failures of the selenium stack at one substation although there have been several trolley-to-track failures and seven operations of the 100-ampere protective fuse.

At the other substation, the record is not so good. On April 3, a substitute selenium stack made up of 20 war surplus 4½-inch diameter plates was installed pending the delivery of a standard 80-ampere unit. This unit showed signs of breakdown (excess current in reverse direction) within two months and was replaced on August 2 by an 80-ampere unit. The latter unit tested OK in October but on November 19, 1948, tests indicated the unit should be replaced again.

The cause of these failures has not been determined. There were six trolley-to-rail faults but the 100-ampere fuse did not operate. The normal average

and peak currents are higher than at the other substation but well within the maximum ratings of the unit. Maximum reverse potentials, as indicated by a recording voltmeter, are in the same order but may be considerably higher under trolley-to-rail fault conditions. In an attempt to eliminate stack failures, the 100-ampere fuse has been replaced with a 70-ampere fusetron in order to reduce maximum currents through the rectifier and the single unit was replaced by two units connected in series. While no failures have occurred since this was done, more time will be required to determine the effectiveness of these measures.

Case V

The substation is located about 3½ miles from the end of a suburban trolley line. The underground cable is routed along the same highway as the trolley and the bond wire is approximately 50 feet long. There is a bond connection through a reversing switch to a pipe line at the same substation and also a reversing switch connection to the trolley rail at a pipe line crossing about one mile from the substation. The mutual resistance effect of these other bonds plus the condition of single track operation and stub end feed to a small town results in very erratic voltage fluctuations between the negative bus and the underground cable plant. Great difficulty was experienced in attempting to obtain satisfactory operation of the reversing switch. Low current values were essential for proper protection and the mechanical vibration of the switch caused by the operation of the rotary converter at the substation made a satisfactory adjustment of the polarized re'ay practically impossible.

As a result of the abov difficulties, the reversing switch was replaced with an 80-ampere selenium stack on October 1, 1948. On December 21, routine tests indicated that the unit still was operating in a satisfactory manner.

An interesting side light on this installation involved the Long Lines Department of the A. T. & T. Company. They were making electrolysis acceptance tests on two full size, corrosion protected trunk cables which pass through this area. These cables are in joint duct runs and their sheaths are bonded to the sheaths of the local cables in manholes adjacent to the substation. With the reversing switch in operation, the A. T. & T. Company measurements were erratic and indicated a number of exposures. After the switch was replaced with a selenium stack, their engineers reported that results were so much better that they found it desirable to repeat all of their measurements in that area.

In order that the nature of the territory and method of installation of the selenium stacks may be visualized more clearly, photographs and a picture diagram of a complete unit have been included.

In conclusion, it should be emphasized that no claim is made to originality in the use of dry disk rectifiers as "One-Way Valves" in electrolysis drainage wires. At least one manufacturing company supplied copper oxide units for such service as far back as 1932. Also, it is known that other engineers have used these units with considerable success. However, very little has been published regarding practical operating experience on existing installations and it was felt that a short paper describing the work done in this territory would be of interest and possibly inspire a more general use of a piece of equipment which limited experience indicates might be helpful in handling electrolysis mitigation problems.

Grateful acknowledgment is made to Mr. E. D. Bossert and Mr. R. W. Kelly for their assistance in procuring the field data needed for the preparation of this paper.

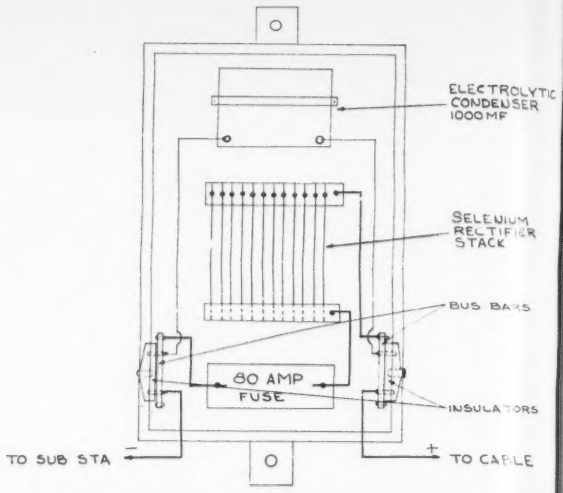


Figure 1—Complete rectifier unit mounting arrangement and wiring diagram.

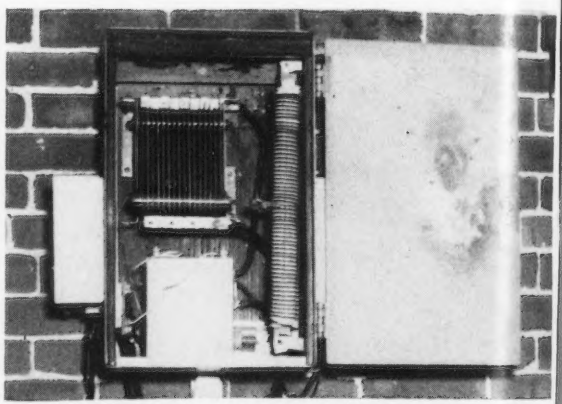


Figure 2—Case IV rectifier unit with cabinet door open.

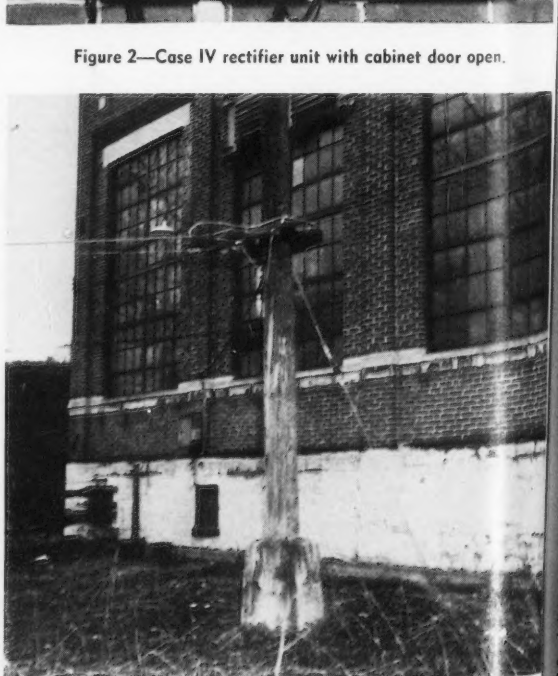


Figure 3—Case III Termination of drainage wires at substation.

Corrosion Resistance of Commercially Pure Titanium*

By G. E. HUTCHINSON and P. H. PERMAR

Introduction

Commercially pure titanium is a light, strong metal which appears to have attractive possibilities as a structural material. The physical and mechanical properties of titanium have previously been reported.[1] There is good evidence that the corrosion-resisting properties of titanium are fully as remarkable as its physical and mechanical properties. This paper presents the results of some preliminary corrosion studies which indicate the principal fields of usefulness, based on corrosion resistance alone. Data are now available based on 120-day sea-water exposure and on a number of laboratory corrosion tests which indicate that the corrosion resistance of titanium potentially qualifies it as a very useful material of construction.

Source of Titanium Used in Tests

THE COMMERCIALLY pure titanium used in this investigation was produced by Remington Arms Company, Inc., from titanium metal sponge manufactured by E. I. du Pont de Nemours and Co., Inc., Pigments Department. Remington Arms Company commercially pure titanium is produced by melting the titanium metal sponge, casting an ingot, followed by forging and rolling to final thickness. Nominal composition of the titanium sheet used is as follows:

Titanium	99+%
Carbon	Approx. 0.3%
Oxygen, Nitrogen, Iron, few hundredths to few tenths percent each	
Other elements	Trace

Resistance to Marine Atmosphere and Sea-Water Corrosion

The sea-water corrosion resistance of a new material possessing a high strength-to-weight ratio is, naturally, of interest to aircraft, marine, and the allied construction industries. Moreover, the ability, per se, to resist corrosion by sea water is a desirable property for any metallic material of construction.

Accordingly, advantage is being taken of the excellent test facilities and services furnished by the International Nickel Company at their Marine Corrosion Test Station, Kure Beach, N. C., to determine how titanium behaves under sea water and marine atmosphere exposures.

At the time these tests were planned, no prior indication of the corrosion characteristics of titanium in marine environment was available. Therefore, the tests included specimens of a number of other materials whose corrosion behavior has been established, with the primary objective of defining the severity of the corrosive conditions during the exposure period.

Commercially pure titanium has been exposed, together with controls of 24S-T3, Alclad 24S-T3, 52S-H34, and Alclad 75S-T6 aluminum, Types 302, 316, and 347 stainless steel, Monel, and Inconel, since midsummer, 1948, in the following tests at Kure Beach:[2,3]

Sea-spray test rack

Marine-atmosphere test lot

Basin

Sea-water, overflow-discharge trough

Aspirator-type, jet-impingement apparatus

High-speed galvanic tester

GILBERT E. HUTCHINSON

Of the Development Division, Technical Department, Remington Arms Co., Inc., Bridgeport, Conn., received his BA in Chemistry from Colby College. He joined Remington as research chemist in 1940, and became group leader in charge of general chemical research in 1946. For the past two years he has been active in titanium corrosion research.

P. H. PERMAR

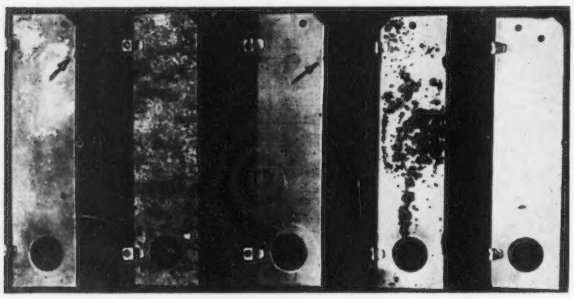
Research engineer with Engineering Research Laboratory of the duPont company, he has had six years' experience with metallurgical and corrosion problems of the chemical industry, particularly with respect to stainless steels, and more recently, titanium. Mr. Permar is a graduate of the Cornell University school of chemical engineering.

★A paper presented at the Fifth Annual Conference of The National Association of Corrosion Engineers at Cincinnati, Ohio, April 11-14, 1949.

All the materials were tested as 1½-in. x 6-in x 1/32 to 1/16-in. strips, except in the jet-impingement and galvanic tests where the specimens were designed to fit the apparatus.

Chemical analyses of the control metals are given in Table I.

A description of the surface conditions before exposure and methods of cleaning after exposure are included in Table II.



1 2 3 4 5

Figure 1—Titanium and control metals after four months' immersion in the basin at Kure Beach. 1. 52S-½H aluminum. 2. Alclad 75ST aluminum. 3. Type 316 stainless steel. 4. Monel. 5. Commercially pure titanium.

TABLE I
Chemical Analysis of Control Alloys Exposed at Kure Beach, N. C.

Aluminum Alloys

ALLOY	Cu	Fe	Si	Mn	Mg	Cr	Zn	Ti	Al
24S-T3	4.54	.30	.15	.58	1.46	....	....	....	Bal.
Alclad 24S-T3:									
Coating	.27	.13	.07	.01	.13	....	....	....	Bal.
Core	4.19	.28	.11	.56	1.39	....	....	....	Bal.
52S-½H	.02	.15	.12	.05	2.53	.21	....	....	Bal.
Alclad 75S-T6:									
Coating	.09	.36	.07	.01	.15	....	1.31	....	Bal.
Core	1.58	.15	.08	.12	2.61	.24	5.90	.05	Bal.

Stainless Steels

ALLOY	Cr	Ni	Mn	P	S	Si	C	Mo	Cb	Fe
Type 302	18.37	8.71	.93	.019	.009	.600	.099	.....	.....	Bal.
Type 316	17.36	12.68	1.60	.024	.023	.44	.053	1.89	.....	Bal.
Type 347	18.58	11.27	1.76	.026	.020	.58	.058	.....	.87	Bal.

Nickel Alloys

ALLOY	Cu	Cr	Ni	Mn	P	S	Si	C	Fe
Monel	29.75	.....	67.85	1.04	.029	.008	.127	.072	0.98
Inconel	.....	14.79	77.63	.20	.010	.008	.183	.056	6.96

Marine Atmosphere Exposure

The sea-spray test rack—80 feet from the ocean—is the most severe atmospheric exposure at Kure Beach; the specimens are frequently wetted by salt mist and spray. After 120 days' exposure, the titanium specimens appeared entirely unaffected, based on visual examination.

Exposure conditions in the marine atmospheric test lot—800 feet from the ocean—are less severe than in the sea-spray test racks. After 120 days, the titanium specimens on this rack also appeared entirely unaffected. After suitably long exposure periods, specimens will be removed from these atmospheric racks for weighing and tensile testing.

Sea-Water Exposure

Additional sets of specimens were totally submerged in the basin, where the water is essentially stagnant, subject only to tidal fluctuation. The results, summarized in Table II indicate that titanium was essentially unaffected, showing no evidence of pitting or crevice corrosion and negligible over-all attack. Typical specimens after exposure are shown in Figure 1.

The effect of increasing the water velocity from essentially zero in the basin to 3 ft./sec. in the sea-water trough increased the severity of corrosion for some materials and decreased it for others. (Table II). All three titanium specimens were totally unaffected and showed no measurable weight loss.

Titanium demonstrated excellent resistance to impingement attack in the aspirator-type, sea-water jet test, in which the specimen was subjected to the action of a submerged jet of sea water containing 2.4% by volume of entrained air. After 30 days' exposure at a jet velocity of 12 ft./sec., and an average temperature of 23.5° C, no appreciable weight loss was

TABLE II
Results of Exposure of Titanium and Control Metals to Corrosion by Sea Water at Marine Corrosion Test Station, Kure Beach, N. C.

MATERIAL	Surface Condition[1]	BASIN, 120 DAYS (3 SPECIMENS)			SEA-WATER OVERFLOW-DISCHARGE TROUGH, 120 DAYS (3 SPECIMENS)		
		Corr. Rate In./Year[2]	Max. Depth of Face Pitting. In.	Max. Depth of Crevice Corr., In.[3]	Corr. Rate In. Year[2]	Max. Depth of Face Pitting. In.	Max. Depth of Crevice Corr., In.
Titanium	Cold Rolled	Nil[4]	None	None	Nil	None	None
Aluminum 24S-T3	Bright	0.0050	0.041	0.020	0.018	0.030	0.050
Aluminum Alclad 24S-T3	Bright	0.00057	0.001	None	0.0022	0.0005	None
Aluminum 52S-H34	Bright	0.0016	0.040	0.030	0.0021	0.007	None
Aluminum Alclad 75S-T6	Bright	0.00090	0.001	None	0.0033	0.0005	None
Stainless Steel Type 302	Bright Cold Rolled	0.0020	0.069[5]	0.062	Nil	0.005	None
Stainless Steel Type 316	Hot Rolled and Pickled	0.00075	0.056	0.043	0.00086	0.036	0.036
Stainless Steel Type 347	Hot Rolled and Pickled	0.0039	0.069[5]	0.175	0.015	0.069[5]	Approx. 1.5
Monel	Cold Rolled and Annealed	0.00190	0.009	0.056	0.0013	0.025	0.047
Inconel	Hot Rolled	0.0017	0.039[5]	0.025	Nil	None	None

[1] Before test, specimens were vapor degreased in perchlorethylene.
[2] After exposure, all specimens except Monel were chemically cleaned in 65% HNO_3 at room temperature, dried in acetone and weighed; Monel was scrubbed with pumice soap, dried and weighed.
[3] Depth of corroded area formed at contact points of porcelain insulators.
[4] Nil indicates a corrosion rate less then 0.0001 in./year.
[5] Specimen perforated.

noted and no surface erosion or corrosion was observed.

La Que and Cox[4] have developed a galvanic series of metals and alloys in sea water. These data, based on both practical experience and on measurement of the potentials of the various materials with respect to a saturated calomel half-cell in sea water flowing at low velocity, provide a qualitative guide to the galvanic relationships of these materials when exposed in contact with each other. Similar data for titanium have been obtained in the high-speed galvanic tester at Kure Beach, which indicate that titanium, with an average steady-state potential of −0.150 volt in sea water flowing at 12 ft./sec. at 25° C, is located near the lower end of the series between Inconel (passive) and Monel (Table III). In cooler water, e.g. 17° C, titanium becomes even more noble, with a steady-state potential as low as +0.1 volt. During these 500-hr. tests no appreciable weight loss occurred and the surfaces of the specimens showed no evidence of attack.

The relative positions of two metals in the galvanic series does not in itself describe the actual galvanic behavior of the two materials because of polarization effects, which actually govern the amount of current flowing during the galvanic corrosion process. Preliminary results of studies of cathodic polarization of titanium at the Marine Corrosion Test Station in sea water flowing at 12 ft./sec. show that titanium polarizes very readily. For example, at a cathodic current density of 1 ma./sq. dm., titanium polarizes to a potential of about −0.5 volt. There is also indication that relatively high current densities (i.e., in excess of 25 ma./sq. dm.) will be required to polarize titanium to the potential of the aluminum alloys.

Titanium is not an anti-fouling metal. Titanium surfaces permit the growth of fouling organisms, although their presence apparently does not promote pitting or other corrosion of the metal.

In addition to a continuation of the atmospheric and sea-water tests just described, tests are currently in progress at Kure Beach to evaluate stress-corrosion cracking, pitting, and the galvanic corrosion behavior of titanium coupled with other metals.

The experiments performed to date indicate that titanium has excellent resistance to corrosion in marine atmospheres and sea water, including freedom from pitting in quiet exposures and freedom from impingement attack at velocities as high as 12 ft./sec. In marine environments, titanium was superior to the controls, and appeared to equal the best known materials, e.g., Hastelloy C and Stellite.

TABLE III

Galvanic Series in Sea Water
(After La Que and Cox[3])

Magnesium
Zinc
Aluminum 52SH
Aluminum 2S
Aluminum 24S-T
Mild Steel
Cast Iron
Ni-Resist
13% chromium stainless steel Type 410 (active)
18-8 stainless steel Type 304 (active)
18-8-3 stainless steel Type 316 (active)
Lead
Tin
Muntz metal
Nickel (active)
Inconel (active)
Yellow brass
Admiralty brass
Aluminum bronze
Red brass
Copper
Silicon bronze
70-30 copper nickel
Nickel (passive)
Inconel (passive)
Titanium
Monel
18-8 stainless steel Type 304 (passive)
18-8-3 stainless steel Type 316 (passive)

Resistance to Corrosion by Chemical Reagents

In the development of corrosion data for a newly commercialized metal, such as titanium, laboratory corrosion tests are the most convenient starting points. It is realized that laboratory data in general are not adequate for design purposes; it is suggested that the present information be used to indicate where additional tests under actual service conditions are warranted.

Comparatively few corrosion data for titanium are given in the literature. In general, the results of previous investigators,[5,6,7,8,9,10] are of the same order as the present data. Differences in metal processing and in specific test conditions may cause variations in results under apparently similar environments. These discrepancies probably will be resolved as experience with titanium is broadened.

Specimen preparation and corrosion-test procedures followed generally accepted methods. Specimens approximately 1 in. long x ½ in. wide and 1/16 to 1/32 in. thick were used, both as-rolled and ground on a 120-grit wet belt. Each of the individual exposure periods was run in 600 ml. of fresh solution, prepared from C. P. reagents and distilled water. Concentrations were expressed as percent by weight. The oxygen content of the reagents used was not purposely controlled, but was that amount obtained by absorption from the atmosphere at the test temperature. No mechanical agitation was employed. Test flasks at room temperature (20-25° C) were covered with watch glasses; those at 80° C (±2° C) and at the boiling point were fitted with finger-type, water-cooled condensers.[11]

The laboratory corrosion tests were run according to several different schedules. In general, the effect of each reagent was evaluated in duplicate tests by means of: a) a multiple-exposure, 240-hr. test, consisting of four periods (24, 96, 96, 24 hr.); b) a single 300-hr. period; and c) two 24-hr. exposures of activated specimens. The typical corrosion rate given for titanium in the majority of reagents shown in Table IV thus is based on fourteen individual corrosion test periods for a total of six test specimens representing several heats of titanium.

The use of varied exposure periods failed to reveal any generally significant correlation of corrosion rate with length of exposure time. Occasionally, how-

ever, "borderline passivity" caused such wide differences in corrosion from period to period that no typical corrosion rate could be determined. In these cases, both the high and low rates are given.

The technique employing activated corrosion-test specimens has been used previously at the Engineering Research Laboratory[12] for obtaining reproducible corrosion-test results on stainless steel alloys in such reagents as H_2SO_4, where borderline-passivity effects often cause highly erratic results. It has been found that satisfactory data are obtained if the stainless steel specimen is exposed in an activated condition (i.e., immediately after removal of the passive film). This procedure is believed to reveal the intrinsic corrosion resistance of the metal and avoids passivation effects other than those introduced by the testing solution itself.

For this activation treatment, the titanium specimen was immersed in a 10% HNO_3, 0.25% HF solution at 25° C for 40 seconds after the start of hydrogen evolution. After activation, the specimen was washed in each of three flasks containing the testing solution at the testing temperature and then introduced directly into the testing flask, also at testing temperature. The washing operation consumed only a few seconds and the specimen was transferred in a glass cradle, without being allowed to dry. Control tests were made to determine a weight-loss correction factor for the activating operation.

TABLE IV
Resistance of Commercially Pure Titanium to Selected Chemical Reagents

Reagent	Conc. by Wt. Percent	Temp. °C.	Typical Corr. Rate In./Yr.	REMARKS
Acetic acid, glacial	99	Boil	Nil[1]	Bright, no wt. loss
Acetic anhydride	99	Room[3]	Nil	Bright, no wt. loss
Ammonium hydroxide	28	Room	Nil	Bright, no wt. loss
Calcium chloride	28	Boil	Nil	Bright, no wt. loss
Carbon tetrachloride + 1% water	100	Boil	Nil	Bright, no wt. loss
Chloroacetic acid	30	80	0.0008	Bright
Chlorine gas[2] (H_2O-sat'd.)	100	75	Nil	Bright, lt. brown stain
Chlorine gas, (dry-H_2O 0.005 percent)	100	30	Ignites & burns	Violent exothermic reaction using finely divided titanium
Chlorine water[2] (Cl_2-sat'd.)	.....	75	Nil	Bright, lt. brown stain
Chromic acid (CrO_3)	10	Boil	Nil	Transparent yellow film
Cupric chloride	40	Boil	Nil	Bright, no wt. loss
Ferric chloride	10	Boil	Nil	Red deposit, bright underneath
Formaldehyde	37	Boil	Nil	Bright
Formic acid	50	Boil	(Nil to 0.2)[4]	Colored transparent film on Nil specimens, gray etch on active sample
H_2S-sat'd. water	.....	Room	Nil	Bright
Hydrochloric acid	5	Room	Nil	Bright
Hydrochloric acid	10	Room	(Nil to 0.02)[4]	Bright, to gray etch
Hydrochloric acid	20	Room	0.02	Uniform gray etch
Hydrochloric acid	37	Room	0.6	Uniform gray etch
Hydrochloric acid	1	Boil	(Nil to 0.08)[4]	Transparent brown film on Nil specimens, gray etch on active samples
Hydrochloric acid	3	Boil	0.2	Uniform gray etch
Hydrochloric acid	5	Boil	0.6	Uniform gray etch
Hydrofluoric acid	1	Room	2.5	Black etch
Anhydrous Hydrofluoric acid	100	Room	0.02	Gray etch with large crater
Lactic acid	85	Boil	0.0002	Bright
Nitric acid	65	Boil	0.009	Brown to blue transparent film
Nitric acid	98	Room	Nil	Bright, no wt. loss
Phosphoric acid	10	80	0.07	Uniform gray etch
Phosphoric acid	85	Room	0.008	Uniform gray etch
Sodium chloride	Sat'd.	Boil	Nil	Bright, no wt. loss
Sodium hypochlorite	5-6% Cl_2	Room	Nil	Bright, no wt. loss
Sodium hydroxide	10	Boil	0.0008	Brown-green iridescent film
Sodium hydroxide	40	80	0.005	Light gray etch
Sodium sulfide	10	Boil	0.001	Blue-Gray iridescent film
Stearic acid	100	180	Nil	Bright, no wt. loss
Sulfur dioxide Sat'd. H_2O	.....	Room	Nil	Bright to yellow film
Sulfuric acid	1	Room	Nil	Bright
Sulfuric acid	5	Room	(Nil to 0.009)[4]	Bright, to lt. gray etch
Sulfuric acid	10	Room	0.007	Gray etch
Sulfuric acid	40	Room	0.06	Gray etch
Sulfuric acid	65	Room	0.07	Gray etch
Sulfuric acid	78	Room	0.6	Gray etch
Sulfuric acid	95	Room	0.1	Gray etch
Sulfuric acid	104	Room	0.2	Gray etch
Sulfuric acid	1	Boil	0.3	Gray etch
Sulfuric acid	5	Boil	0.9	Gray etch
Sulfuric acid + 0.5% MnO_2	40	Room	(Nil to 0.06)[4]	Bright, to gray etch
Sulfuric acid + nitric acid	52% H_2SO_4 48% HNO_3	Room	0.001	Slight iridescence
Sulfuric acid + nitric acid	14% H_2SO_4 83% HNO_3 3% H_2O	Room	0.0008	Iridescent film
Trichlorethylene (Unstab.) + 1% H_2O	100	Boil	Nil	Bright, no wt. loss
Trichlorethylene (Stab.) + 1% H_2O	100	Boil	Nil	Bright, no wt. loss
Zinc chloride	10	Boil	Nil	Bright, no wt. loss
Sulfur, molten	100	240	Nil	Thin blue film
Sulfur, + water	.....	Room	Nil	Bright, no wt. loss

[1] Nil = corrosion rate of less than 0.0001 in./yr.
[2] Plant test, 30 days in addition to laboratory test.
[3] Room temperature = 20 to 20° C.
[4] "Borderline passivity".

Reagents Not Reactive with Titanium

The potential commercial use of titanium as a corrosion-resistant material is indicated by the very low corrosion rates shown in a number of reagents normally considered to be corrosive to most metals. For instance, wet chlorine gas, hot chromic acid, and hot ferric chloride solutions are not corrosive to titanium. In many of the reagents in the "not-reactive" class, corrosion was entirely negligible, evidenced both by no measurable weight loss and by freedom from discoloration or tarnish of the specimen.

Titanium has shown complete immunity from corrosion by chlorine-saturated water and water-saturated chlorine gas in laboratory and plant exposure tests. The only discernible effect of exposure to water-saturated chlorine gas is an occasional transparent brown "tobacco stain" on the metal surface. However, recent experiments have demonstrated that finely divided titanium may be ignited and rapidly consumed when exposed to pure dry chlorine gas. The addition of water vapor apparently inhibits the reaction; for example, shavings of titanium may ignite in chlorine containing less than approximately 0.005% by weight of water, but apparently are not reactive if the water content is above 0.013%. The probability of igniting massive material apparently depends on 1) the state of subdivision of the surface, i.e., whether or not small particles (such as are formed on a rough-machined surface) are present, and 2) the temperature. No data are available at present on the temperature at which spontaneous ignition begins.

The chloride salts investigated in this study have caused no appreciable corrosion or pitting of titanium. Boiling 40% cupric chloride and boiling 10% ferric chloride, which are extremely corrosive to stainless steels and most other metals and alloys, did not corrode titanium. In addition, boiling saturated NaCl, boiling 10% $ZnCl_2$, boiling 28% $CaCl_2$, or NaOCl at room temperature neither caused measurable weight loss nor dulled the brightness of the metal surface.

Nitric acid in all concentrations up to 98% at 20-25° C has a negligible effect on titanium. For example, no measurable weight loss occurred after six months exposure to 95% HNO_3 at 20-25° C. At elevated temperatures, however, titanium reacts slowly with HNO_3; e.g., boiling 65% HNO_3 produces a corrosion rate of about 0.009 in./yr.

Neither water saturated with H_2S nor water saturated with SO_2 at 20-25° C caused measurable weight loss or discoloration. Likewise, neither molten sulfur at 240° C nor a water-sulfur mixture at 20-25° C had any adverse effects on titanium.

The strong alkalis shown in Table IV appear to react slowly with titanium. Boiling 10% NaOH and boiling 10% Na_2S both result in moderate corrosion; however, 40% NaOH at 80° C causes marked acceleration of corrosion. Ammonium hydroxide, on the other hand, is apparently entirely unreactive.

Several organic acids have been evaluated: boiling glacial acetic acid, acetic anhydride at 20-25° C, 30% chloroacetic acid at 20-25° C., and stearic acid at 180° C caused negligible attack on titanium. Boiling 85% lactic acid resulted in measurable, but very slight, corrosion.

Chlorinated solvents, refluxed in the presence of water for as long as 300 hr., do not become corrosive to titanium. Carbon tetrachloride and trichlorethylene (either unmodified or stabilized against decomposition) were not corrosive.

Reagents Reactive with Titanium

Study of Table IV reveals that a number of reagents cause measurable corrosion of titanium, while many more have little or no effect on the metal. In general, the corrosion resistance of titanium appears to be a matter of extremes. Either the metal is practically unaffected, or it corrodes at an appreciably rapid rate.

Purely for purposes of discussion, reagents in which titanium corrodes at a rate in excess of 0.005 in./yr. are considered to be reactive. In this category are:

Formic acid—50% boiling
Hydrochloric acid—greater than 5% at 25° C.; 1% or greater, boiling
Hydrofluoric acid—all aqueous solutions
Nitric acid—65%, boiling
Phosphoric acid—10% at 80° C.; 85% at 25° C.
Sulfuric acid—5% and greater at 25° C.; 1% and greater at 80° C.

Boiling 50% formic acid is an excellent example of the borderline passivity phenomenon in the corrosion of titanium. Early tests revealed wide variations in corrosion rates; for example, one specimen would show no weight loss, and a companion sample would corrode at a rate as high as 0.22 in./yr. Consistently high corrosion rates were obtained, however, when the specimens were activated by the HNO_3-HF pickling technique. Formic acid causes uniform metal loss of titanium with accompanying surface roughening and accelerated end-grain attack, but no pitting.

Titanium is apparently resistant to 5% hydrochloric acid at 20-25° C, but is attacked if the concentration is increased to 10%. Borderline passivity of titanium is observed in 1% hydrochloric acid at the boiling point. For example, the specimen may suffer no weight loss during one period, and may corrode at the rate of 0.02 in./yr. during the next period. A third immersion may produce no additional weight loss. Stronger HCl solutions (20 or 37%) at room temperature cause severe general corrosion, often with the development of a purple color (titanous ion) in the test solution.

Dilute hydrofluoric acid at room temperature is extremely corrosive to titanium. Several specimens immersed in 10% HF dissolved in less than 1 hour. Anhydrous HF, at room temperature, on the other hand, corrodes titanium at a more moderate rate, approximately 0.020 in./yr.

Boiling 65% HNO_3 exhibits approximately the same corrosion rate for titanium as for properly heat-treated austenitic stainless steels. Using five 48-hour periods,[11] an average corrosion rate of 0.009 in./yr. has been observed. Boiling 65% HNO_3 causes general over-all attack, with some end-grain corrosion. The specimens are usually strongly colored; the surface first assumes a light brown stain which darkens and becomes more purple as corrosion proceeds.

Phosphoric acid, in hot, dilute (10%) solutions and in more concentrated form (85% at 20-25° C) causes active corrosion of titanium by a mechanism of general over-all attack.

Sulfuric acid solutions, in general, are highly corrosive to titanium. Sulfuric acid is usually more corrosive than HCl of the same concentration, the practical concentration limits being about 1% at 20-25° C, and considerably less than 1% (actual limit not determined) at 80° C.

The existence of passivity effects is one of the points of similarity between titanium and the stainless steels. It has been amply demonstrated that stainless alloys either may be extremely corrosion-resistant or may suffer rapid attack, depending on the effective presence of a protective layer or film, usually maintained in the presence of oxidizing media. In general, titanium also shows improved corrosion resistance in oxidizing environments.

An impressive reduction in attack by sulfuric acid and by hydrochloric acid is shown if the acid contains an oxidizing agent such as HNO_3 or is oxygenated. Mixed acids, containing as much as 50% H_2SO_4 in the presence of HNO_3, do not cause severe corrosion of titanium. Recent plant experience in a nitrator containing organic materials, 50% H_2SO_4, and from ½ - 3% HNO_3 at 55 - 60° C, revealed that titanium corroded at a rate of only 0.002 in./yr. Laboratory tests of 6 hours duration reveal that the addition of HNO_3 to HCl to form aqua regia reduces the corrosion of titanium to a surprisingly low level. Aqua regia, containing 3 volumes of 37% HCl and 1 volume of 65% HNO_3, does not cause appreciable corrosion of either as-ground or activated specimens of titanium. Aqua regia at elevated temperatures will develop a transparent brown film on titanium after several hours exposure, whereas aqua regia at room temperature does not discolor the metal.

Oxygen has been shown to have a beneficial influence on the corrosion of titanium in dilute H_2SO_4

TABLE V

Effect of Aeration of Test Solution on Corrosion of Titanium at 80° C. (Activated Specimens)

Reagent	Concentration Percent	CORROSION RATE, In./Yr.		
		O_2-Saturated	Natural Aeration	N_2-Saturated
Hydrochloric acid	1	0.0014	0.0012	0.011
Hydrochloric acid	2	0.0055	0.0060	0.032
Hydrochloric acid	3	0.0075	0.040	0.054
Sulfuric acid	1	0.0028	0.054	0.072
Sulfuric acid	2	0.0060	0.11	0.12
Sulfuric acid	3	0.19	0.18	0.17

and HCl solutions at 80° C. The results shown in Table V indicate that increasing the oxygen content of the test solution by bubbling O_2 through the liquid will in general reduce the corrosion rate, and that removing dissolved oxygen by purging the solution with N_2 will cause an appreciable increase in corrosion of titanium. The data shown in Table V are the average of duplicate tests, of three 24-hour periods each. The specimens were activated in HNO_3-HF immediately before each period. By this means, reproducible period corrosion rates were obtained.

It also has been observed that the addition of MnO_2 to sulfuric acid solutions in some cases reduces the corrosion of titanium. Although a corrosion rate of 0.06 in./yr. in 40% H_2SO_4 at 25° C can be reduced to nil by the addition of 0.5% MnO_2, the effect is not consistent. These data suggest the possibility of practical corrosion inhibition of titanium by the addition of oxidizing agents to process solutions.

The corrosion of titanium takes the form of "general attack." The surfaces of corroded specimens were generally of uniform texture, free from areas of localized attack. No bona fide cases of intergranular attack have been observed. In cases where severe corrosion occurred, end-grain attack typical of other rolled metals under severely corrosive conditions also was noted for titanium.

Summary

A preliminary survey has been made to evaluate the resistance of commercially pure titanium to sea water and atmospheric corrosion and to high-spot the behavior of the metal in a group of selected chemical reagents.

Results to date reveal that titanium possesses outstanding resistance to sea-water corrosion and to marine atmospheric weathering. While titanium is attacked by several common reagents, it possesses outstanding resistance to a number of media, including water-saturated chlorine (but not dry chlorine), chloride salts, and highly oxidizing reagents, which are corrosive to most other metals. Good resistance to corrosion, coupled with its excellent strength-weight properties, indicate promising applications for commercially pure titanium.

Acknowledgments

The authors wish to thank F. L. La Que and the Kure Beach Staff of the International Nickel Company for their advice and assistance in obtaining the sea water exposure data. W. J. Barth carried out the majority of the laboratory chemical corrosion tests.

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DISCUSSION

Questions by Mr. Fred W. Schmitz, Commercial Solvents Corp., Terre Haute, Ind.:

"Despite the difficulty and high cost of fabricating tantalum, is it not likely that because of the extreme resistance of this metal to nitric and hydrochloric acids tantalum will compete severely with titanium for such service? Inasmuch as the choice of equipment materials ultimately depends on cost as well as length of service, how do the indicated costs (commercial scale production) of titanium compare with the present costs of tantalum and other alloys now in use?"

Author's Reply:

At this early stage in its development, it is virtually impossible to predict the ultimate cost of titanium. Our experimental production costs are such that it is now necessary for us to charge $15 to $30 per pound for titanium in primary fabricated forms such as sheet and rod, where appreciable quantities are required. We expect to reduce the price of titanium to a few dollars per pound within a few years with a prospect of further reduction. Our program is directed toward making titanium and titanium alloys available at prices which will permit their use in structural and engineering services. In making cost-per-pound comparisons, it should be remembered that titanium has roughly one-half the density of many other structural and corrosion-resistant alloys.

Question by Mr. Paul Gegner, Pittsburgh Plate Glass Co., Barberton, Ohio:

I would like to know the corrosion resistance of titanium to strong alkalies, particularly caustic soda at elevated temperatures.

Author's Reply:

As mentioned in the paper, the strong alkalies appear to react slowly with commercially pure titanium. Ammonium hydroxide, on the other hand

apparently is entirely unreactive. Typical laboratory corrosion rates are:

28% ammonium hydroxide at room temperature ..... nil
10% boiling sodium hydroxide ..... 0.8 mil per year
40% sodium hydroxide at 80° C. ..... 5 mils per year

Question by Dr. Mars Fontana, Ohio State University, Columbus, Ohio:

What is the prior history of the titanium specimens studied particularly with regard to working and heat treatment? Were the specimens hot worked or cold worked? Were the specimens heat treated in any way? A few remarks on "purity" or chemical composition of the metal would add to the value of this good paper.

Author's Reply:

The titanium specimens were prepared from commercially pure sheet material produced by the Remington Arms Company, Inc., from titanium metal sponge manufactured by E. I. du Pont de Nemours, Inc., Pigments Department. This sheet was produced by melting titanium metal sponge, casting an ingot, followed by forging and rolling to final thickness. The nominal composition of the titanium sheet used is as follows:

Titanium ..... 99+%
Carbon ..... Approx. 0.3%
Oxygen, Nitrogen, Iron ..... Few hundredths to few tenths percent each
Other elements ..... Trace

Tests run on both annealed and cold rolled sheet show no significant differences in corrosion rates.

Question by Mr. F. T. Wood, Jr., Douglas Aircraft Co., Los Angeles, Calif.:

What effect does red fuming nitric acid have on titanium?

Author's Reply:

Our laboratory tests have shown no corrosion in 98% nitric acid at 80° C. It has been reported that titanium also shows good resistance to red fuming nitric acid.

Question by Mr. Tom R. Watson, Dominion Magnesium Ltd., Toronto, Canada:

How pure is "Commercial Purity Titanium"? What is the hardness rating of the metal?

Author's Reply:

Remington Arms Company commercially pure titanium has the nominal composition shown in preceding reply.

Typical approximate hardness values for commercially pure titanium sheet are:

	Annealed	Full Hard
R_A	60	65
R_C	14	30
VHN	245	300

Mr. B. B. Morton, International Nickel Co., New York, New York:

What are some of the physical and mechanical properties of titanium? What are some of the physical properties of the titanium metal, especially the density and the thermal coefficient of expansion?

Author's Reply:

This subject is covered in detail in a recent publication by C. I. Bradford, "Physical and Mechanical Properties of Commercially Pure Titanium," Paper No. 6, Titanium Symposium, Department of the Navy, Office of Naval Research, Washington, December, 1948. Some of the more interesting physical and mechanical properties of Remington Arms Company commercially pure titanium are:

Physical Properties

Density	4.5 gm/cc 0.16 lbs/in³
Melting Point	3140°F.
Linear Coefficient of Thermal Expansion	5.0 x 10^{-6}/°F.
Specific Heat Btu/lb/°F or Cal/gm/°C	0.13
Electrical Conductivity (at room temperature)	3.2% I.A.C.S.
Thermal Conductivity Btu/ft²/in./°F/hr.	105

Room Temperature Mechanical Properties (Annealed Sheet)

Tensile strength	80,000 psi
Yield strength (0.2% Offset)	72,000 psi
Elongation (2" Gauge Length)	25%
Modulus of Elasticity	$14.5 - 15.5 \times 10^6$ psi

The Study of Corrosion in the Colleges ★

By HUGH J. McDONALD*

Introduction

As one of its tasks for the year, the American Coordinating Committee on Corrosion** decided in 1947 to survey the present status of corrosion, teaching and research, in the colleges of the United States and Canada. The author was at the time secretary-treasurer of the committee and the responsibility for the survey fell to his lot. Individual letters were sent to all colleges which it was thought had offered corrosion course work in the past. The list of colleges to which the initial letter was sent was enclosed with the request for information and additions to the list, of other colleges which might be offering work in corrosion. In this way, quite a number of colleges were approached on the matter. It was found that some schools had at one time or another offered work in corrosion but were not doing so at present; others included a small number of lectures on corrosion as integral parts of courses in electrochemistry or on materials of engineering construction. The present paper attempts to present the survey results of the institutions which regularly offer course work in the field of corrosion*** and in some cases also conduct research. The list of schools includes: Case Institute of Technology, Colorado School of Mines, University of Colorado, Illinois Institute of Technology, Lehigh University, Massachusetts Institute of Technology, University of Michigan, The Ohio State University, The University of Pittsburgh, Queen's University and the University of Texas. Some few additional colleges which include at least some lecture work in corrosion as integral parts of courses in physical chemistry, electrochemistry or materials of engineering construction include the University of Oregon and the University of Toronto.

On the whole, research work being done in the English-speaking countries is of a less fundamental nature than that being done by some European research groups, especially in the USSR. The work of G. V. Akimov, N. D. Tomashov and A. Frumkin and their colleagues, for example, as shown by their recent books and papers has been conspicuous by its contribution to the fundamental, mechanistic theory of corrosion processes.

Observations and Commentary

ALTHOUGH it is evident from the survey that the need for establishing corrosion as a field of study worthy of university instruction is now firmly established, yet there is much room for improvement, especially when it is remembered that the destruction of metals, amounting to several hundreds of millions of dollars annually, represents one of the country's greatest economic losses. Consideration of the mileage of underground pipelines and cables alone in this country will give some idea of the large investment that must be protected. A recent survey shows there are in the United States, 965,000 miles of buried pipelines carrying oil, gas, and water; 425,000 miles of metal track and 100,000 miles of underground cable. On the underground pipelines alone, there is an estimated annual loss of $50,000,000. It is evident that an increasingly large proportion of the annual production of metals is required to replace that rendered unserviceable by corrosion. The more rapid depletion of top grade ores, such as those of the Mesabi range in Minnesota, is another reason for concern over the wastage due to corrosion.

Other than on underground structures, corrosion is a problem in the transportation industry, such as railroads, ships and planes; in the chemical industry, in refrigeration, waterworks, food packing, etc. The government and armed forces also are involved in the problem because of thousands of tons of intricately-built equipment, now stored, which must be ready for action on notice ranging all the way from a few months to perhaps 20 years.

Although, as has been pointed out, the understanding of corrosion processes possessed by those investigating the subject undoubtedly is greater than it was 25 years ago, knowledge of the subject possessed by the general body of scientists may be more limited than formerly. Even some who are closely concerned with corrosion problems in engineering and industry know very little about the scientific causes of corrosion. Large sums of money, and much time and effort, have been wasted in searching for an empirical cure for a phenomenon which was not sufficiently understood. It has become obvious during recent years that the old hit-or-miss methods, or progress by trial and error, never can reach the desired goal and only by a better understanding of the chemical and physical forces which cause metals to corrode on the part of those conducting tests and experimental work can an effective defense be devised.

Unfortunately for progress in the field, corrosion research is plagued by a sustained lack of agreement in several quarters, for example, the nature of stress corrosion cracking, the phenomena of passivity and the mechanism of inhibitor action. The inability to settle the ghosts and douse the continued propagation of unsound principles in the corrosion field seems to be more serious than in some others. Several schools of thought have developed as to the causes and mechanism of these phenomena and the followers of each school go blithely on their way, seemingly ignoring the work of the other schools—and even disregarding established experimental facts when not in agreement with some pet hypothesis, or simply not reading the opposing literature. It is not hard to understand, therefore, that among pure scientists, many think corrosion possesses no scientific interest, or that corrosion reactions do not obey any well-defined laws. Actually laws do exist as in other fields of chemistry—many of them simple and capable of ready interpretation—but the direct application of chemical kinetics to reactions whose velocity often decreases with increasing temperature, or of thermodynamics to reactions which are quite possible but do not occur, demands a flexibility of viewpoint not always found among orthodox chemists or metallurgists.

The status of the science of corrosion will not have reached maturity until every engineering student is subjected to at least the fundamentals of the subject, and until the valiant effort of the few university workers in the field is properly supported financially by industry and government. Although many industries in which corrosion is a prime concern have, in the past, employed promising young scientists to do basic research, the pressure of events has usually forced them into "trouble-shooting" problems of customers' service. Only when the realization dawns that an investment in corrosion research, upon which the success of the much larger investment in metals, fabrication and installation depends, is worthy of closer scrutiny, will the empirical art of metal protection give way to the science and engineering of corrosion control.

APPENDIX

REPORT ON THE SURVEY

Case Institute of Technology, Cleveland, Ohio

The following description of the courses offered

★ Voluntarily Submitted for Publication April 3, 1949.

* Professor of Physical Chemistry, Loyola University School of Medicine, Chicago, Ill. Formerly, Professor of Chemistry and Director, Corrosion Research Laboratory, Illinois Institute of Technology, Chicago, Ill.

** Disbanded in spring 1948. Its functions were taken over by the Inter-Society Corrosion Committee of the National Association of Corrosion Engineers.

*** A detailed listing of course content, instructor, level at which instruction is given, etc., may be found in the Appendix.

was submitted by C F. Prutton,* head, Department of Chemistry and Chemical Engineering:

Met. 210, Oxidation and Corrosion of Metals, Graduate Evening Division.

The thermodynamics and physical factors affecting the mechanism and rate of oxidation and corrosion of metals and alloys; fundamental anlyasis of scaling and internal oxidation covering the effects of the oxide coating, time, temperature, catalysts, and atmosphere; the various types of corrosion and the effects of the numerous variables on these processes are discussed together with preventive measures against scaling and corrosion. (Prerequisite-Met. 100, Physical Metallurgy; Chem. 32, Physical Chemistry for Metallurgists.)

Chem. 292, Corrosion, Graduate

A survey is made of theories of corrosion with particular emphasis on electrochemical theory. Thermodynamic principles and their applications are reviewed and consideration is given to reversible and irreversible electrochemical processes. Corrosion prevention in chemical industries is stressed. Corrosion testing, stress corrosion, inhibition, passivity and cathodic protection are among the topics considered.

Case is engaged in a number of corrosion research projects and plans to extend both research and course work in the field.

Colorado School of Mines, Golden, Colorado

The report which was submitted by L. W. Hartkemeier, of the Chemistry Department, indicates that the course is given to the senior students in Petroleum Refining and consists of three hours laboratory work per week for one semester, the lecture work report is required on the data and results of each being included in this three-hour period.

Chem. 416-L Corrosion

Introduction to the study of corrosion; preparation of experimental accelerated corrosion tests; cathodic protection; galvanic action; effect of solution agitation; concentration cells; inhibitors; pitting. A written test, including explanations and conclusions to be drawn from the work.

University of Colorado, Boulder, Colorado

The following information pertaining to the course in corrosion was submitted by F. A. Rohrman, Executive Director of Research for the University. The course, entitled "Corrosion," is given at the graduate level, and is offered to chemical enginering graduate students. It consists of three hours of lecture and recitation for one term; there is no laboratory work. At present the instruction is given by Dr. Roman T. Koenig. A considerable amount of work at the university is devoted to thesis direction in the field of corrosion, under the direction of Rohrman and Koenig.

* Presently vice-president and director of operations, Mathieson Chemical Corp., N. Y. C.

Illinois Institute of Technology Chicago, Illinois

The present lecture course, which is given on the senior level, is presented by William A. Colner of the Armour Research Foundation of Illinois Institute of Technology, as a two-hour lecture course for one semester. It is offered only in the evening.

Met. Eng. 421. Corrosion

The electrochemical mechanism and rates of corrosion reactions, spontaneity of corrosion processes, inhibitors, stress corrosion cracking, soil corrosion, remedial treatments and protective measures.

In addition to the lecture course in corrosion, the institute maintains the Corrosion Research Laboratory in the Department of Chemistry, wherein fundamental aspects of corrosion such as the high temperature reactions of gases with metals, the mechanism of elementary cathodic processes, and stress corrosion cracking of mild steel are being investigated currently. It is possible for graduate students to arrange for thesis work in corrosion by special arrangement with the Department of Metallurgical Engineering.

The facilities of the Corrosion Research Laboratory are open to outside agencies who may be interested in sponsoring fundamental research work of a publishable character.

Lehigh University Bethlehem Pennsylvania

The following information concerning the corrosion work being done at Lehigh was submitted by W. Beck, Director of the Corrosion Research Laboratory, which is organized as a part of the Department of Metallurgical Engineering.

The course is entitled "Corrosion of Metals, Science and Engineering," with special consideration of electrochemical elements and selected applications to practical problems. It consists of three hours lecture per week for one semester, and covers the following topics: Corrosion in the atmosphere, in architecture and aircraft; corrosion in water, especially sea water and in shipbuilding; corrosion underground, with a consideration of the causes and prevention of stray currents; corrosion and construction, including topics such as corrosion in welding, riveting, etc.; intercrystalline corrosion, corrosion fatigue and corrosion cracking; corrosion problems in the army.

In addition to the lecture work in corrosion, Lehigh offers the facilities of its Corrosion Research Laboratory to graduate students for work on thesis problems, and to other parties outside the University who are interested in sponsoring research on the subject.

Massachusetts Institute of Technology, Cambridge, Massachusetts

The nature of the program in corrosion at MIT was submitted by H. H. Uhlig, Associate Professor of Metallurgy, who is also in charge of the Corrosion Laboratory.

The course, which consists of two hours of lectures for one semester, is given in the Department of Metallurgy and is available to seniors and graduate

students. The course content includes importance of corrosion, forms of corrosion, such as uniform attack, pitting, dezincification, intergranular corrosion, corrosion fatigue and stress corrosion cracking; the electrochemical theory of corrosion, types of cells, half-cell potentials, polarization, passivity; corrosion of iron and steel in aqueous media, the atmosphere and in soil; corrosion control, cathodic protection; metallic, inorganic, organic and chemical conversion coatings; inhibitors and passivators; alteration of environment; alloying; high temperature corrosion; non-ferrous metals and alloys; principles of corrosion testing.

In addition to the course work, facilities for research both by graduate students and outside interests are made available in the Corrosion Laboratory.

University of Michigan
Ann Arbor, Michigan

The description of the work being done at Michigan is based on the report made by C. A. Siebert, Associate Professor of Metallurgical Engineering. A course, No. C & M 217, entitled "Corrosion and High Temperature Resistance of Metals," consisting of three hours lecture for one semester, is offered to first-year graduate students in chemical engineering. The prerequisite for the course is one semester of physical metallurgy. Approximately 50 per cent of the course is devoted to the high temperature behavior of metals, such as creep, stress rupture, etc., and the other 50 percent is devoted to the subject of corrosion. An outline of the course content for the corrosion half of the course is listed below:

Fundamental concepts and theories of corrosion; concentration cells and other electrolytic effects; effects of variables, such as temperature, velocity, etc. on corrosion; passivity; polarization; stress corrosion; protective films; a general discussion of the corrosion of the following in solutions that are reducing or oxidizing in nature, contain chlorides, etc. a) iron and plain carbon steel, b) stainless steels, c) copper and copper alloys, d) aluminum and magnesium and their alloys, e) nickel and nickel alloys.

The subject of oxidation or scaling of metals at elevated temperatures is included in the part of the course devoted to the high temperature properties of metals.

The Ohio State University
Columbus, Ohio

The status of studies in corrosion at the Ohio State University was reported on by M. G. Fontana, Chairman, Department of Metallurgy, and Director of the Corrosion Research Laboratory. Corrosion courses now offered at the University are as follows:

Metallurgy 730. Corrosion of Metals and Alloys

Three credit hours. Two lectures and two hours of laboratory each week. Prerequisite, senior standing in chemical or metallurgical engineering. Theory and forms of corrosion with a study of the variables involved. Methods of corrosion testing and actual testing in the laboratory. Interpretation and expression of corrosion data. Methods of combating corrosion. Properties and uses of corrosion resistant materials. Beginning in 1948-49, this course will be required for a bachelor's degree in metallurgical engineering.

In addition to this course work, thesis problems involving corrosion studies are open to undergraduates for the senior thesis and to graduate students for the M.S. and Ph.D. degrees. For the year 1948-49, the following two additional courses are being scheduled:

Metallurgy 731. Advanced Corrosion

Three hours credit. Three lectures or recitations per week for one quarter. General prerequisite must include Metallurgy 730. Graduate students only. Advanced studies of corrosion with emphasis on theory. Designing of equipment to minimize corrosion. Study of new developments in corrosion and corrosion resistant materials. Review of outstanding literature. The reporting and interpretation of corrosion data. Economic considerations of corrosion resistant equipment.

Metallurgy 830. Advanced Corrosion Laboratory

Four to six credit hours. Every quarter. General prerequisites must include Metallurgy 730 and 731, and permission of the instructor. Not open to students selecting a corrosion problem for thesis work (M.S. or Ph.D.) in metallurgy. A laboratory investigation of a specific corrosion problem.

The University of Pittsburgh
Pittsburgh, Pennsylvania

Corrosion work at the University of Pittsburgh is given by the Department of Metallurgical Engineering; the report below was submitted by H. E. Trout, Jr. who is handling the course.

The course is divided into two terms of work, the first consisting of two hours of lecture weekly wherein a background of theory is given. The first term's content is described in the bulletin of the School of Engineering and Mines in the following way:

Corrosion of Metals

Theories of corrosion, electrochemical theories; influence of manufacture, treatment and composition on corrosion; influence of external factors (temperature, aeration, stress, bacteria, etc.) on atmospheric, underwater and underground corrosion. Corrosion testing; prevention of specific types of corrosion; corrosion problems as related to particular industries.

The second term is given as a seminar, meeting alternate weeks for some three hours or so at each session. In this term, those phases of corrosion background for special uses, i.e., non-ferrous, special steels, etc., are reported upon by the students who have been assigned fairly broad topics without restrictions as to modern sources of information which they should survey. Also, protective coatings and special problems in various industries are discussed. Each individual reports at alternate sessions.

The course is limited to graduate students in Metallurgical Engineering and at present there is no laboratory work given. It is hoped that this phase will be developed later on. The first term is a prerequisite for enrollment in the second, but since an

attempt is made to give a reasonably broad, general theoretical background in the first term, completion of both terms is not compulsory.

Queen's University
Kingston, Ontario, Canada

D. W. Marshall reports that a course is given to the fourth year Chemical Engineering students consisting of one hour lecture per week for the whole school year. At present there is no laboratory course in the subject.

Briefly the course covers the theory of corrosion and the factors which influence the rate of corrosion. Following this, corrosion under various conditions such as atmospheric, sea-water, underground and special cases which may be met in chemical work are covered. The selection of material and the design of equipment to meet special corrosive conditions is the final topic dealt with.

The University of Texas
Austin, Texas

Corrosion at the University of Texas is taught mainly in the Department of Chemistry. Norman Hackerman, Associate Professor of Chemistry, has furnished the following account. About one-quarter of the graduate course numbered Chemistry 375 and entitled "Theoretical Electrochemistry and Corrosion" is devoted to corrosion per se. About one-quarter of another graduate course also taught by Hackerman, Chemistry 395K, "Surface Phenomena," is also devoted to reaction and adsorption at metals surfaces. In addition, graduate students interested in corrosion meet, informally, in a seminar once a week together with Dr. Hackerman to discuss various phases of the subject.

There are no courses on corrosion listed in the engineering school's bulletin although the subject is considered in courses on engineering materials, such as Chemical Engineering 350, and in a course on water treatment, Chemical Engineering 365. The subject is also treated in a course on the metallurgy of steel, Mechanical Engineering 351.

In addition to formal course work, the university also offers thesis direction (M.S. and Ph.D. in chemistry) where the subject matter of the thesis may deal with some underlying principle in corrosion. Research work at present deals mainly with the mechanism of corrosion inhibition, adsorption at surfaces and the phenomena of passivity.

Other Colleges Offering Corrosion Work

In addition to the colleges whose contributions to corrosion study are described above, some few additional ones offer some course work in corrosion, or conduct research in the field. Pierre Van Rysellberghe at the University of Oregon, Eugene, Oregon, is doing some very interesting research in applying the polarograph to elucidate corrosion mechanisms and in developing, by the application of thermodynamics, mapped areas indicating the conditions under which various corrosion products may form. In addition, some lectures on corrosion form part of one of the more advanced courses covering special topics in physical chemistry.

The University of Toronto also offers some lectures on corrosion as part of a course for chemical engineering students.

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Electrochemical Behavior of Zinc and Steel In Aqueous Media*

By R. B. HOXENG and C. F. PRUTTON

Introduction

Zinc is one of the metals most widely used as a protective coating for iron and steel. Aside from economic advantages there are two factors which account for the widespread use of zinc coatings for corrosion resistance; first, the natural corrosion resistance of zinc; and second, the electrochemical protection afforded to the steel base at bared areas. When contacting zinc and steel are exposed to an electrolyte, a galvanic cell is formed in which the steel usually is cathodic and is protected by the galvanic current from the anodic zinc. Because of this protection, certain zinc coated steel products have come to be known as "galvanized steels."

One of the large outlets for galvanized steel is the handling of hot and cold domestic water supplies. By and large this has been a very successful application. However, in recent years there have been several reports of unsatisfactory performance of galvanized steel in hot water systems. Since it generally is agreed the quality of galvanized steel has not deteriorated, the increased corrosion has been attributed to more severe service conditions. Premature failures usually are explained simply as a failure of the zinc to adequately protect the base steel at bared areas, with the assumption that the zinc remains anodic to the steel. Of far more serious consequence is the fact that investigators have reported instances where the zinc coating apparently became cathodic to the base steel. Such an electrochemical relationship, termed a "reversal," could lead to early failure of the product and is therefore of great economic importance to users as well as to manufacturers of galvanized steel. The Committee on Steel Pipe Research of the American Iron and Steel Institute has sponsored a fundamental investigation to determine the effect of electrolyte composition and temperature on the electrochemical relationship between zinc and steel in natural and industrial waters. Sufficient progress has been made in this investigation to show that electrolyte composition is of even more importance than temperature and it was deemed advisable to present at this time the results obtained so far.

★ A Paper presented at the Fifth Annual Conference, National Association of Corrosion Engineers, Cincinnati, Ohio, April 11-14, 1949. Based on data developed in a research project sponsored by Committee on Steel Pipe Research, American Iron and Steel Institute. Abstracted from a thesis submitted in partial fulfillment of the requirements for the Ph D. degree in Chemistry.

R. B. HOXENG

In charge of a research project into the corrosion behavior of galvanized steel pipe sponsored by the American Iron and Steel Institute at Case Institute of Technology, he has done graduate work in physical chemistry at Iowa State College, University of Pittsburgh, Case Institute (PhD, 1949), worked for the Manhattan Project, and done corrosion research at Iowa State College, University of Chicago and Aluminum Co. of America.

C. F. PRUTTON

Vice-president, director of operations and director of research of Mathieson Chemical Corp., he is a graduate of Case School of Applied Science and holds a PhD from Western Reserve University. He has been head of the Case department of chemistry and chemical engineering, a consultant for the War Production Board, Dow Chemical Co. and Lubrizol Corp., is a member of numerous technical societies, author of many technical papers, a text book and holds more than 100 patents.

Previous Work

IT LONG HAS BEEN realized that zinc coatings act in two ways to reduce steel corrosion—first, they serve to keep the electrolyte away from the steel, and then when the steel does become exposed it is protected by the zinc coating through electrochemical action.

Realization of the important role of the zinc coatings led to extensive studies of the factors affecting the corrosion rate of zinc, per se. These investigations were supplemented with tests on galvanized steel to obtain further information on the protection of steel by zinc coatings.

Britton[1] undertook to determine whether the zinc-iron alloy layer present on galvanized steel would electrochemically protect the base steel. He found that these alloys became cathodic to steel and concluded that "the alloy layer is of no use in providing electrochemical protection to iron, though zinc appears to be potentially of great value in this respect." Instances in which rapid failure of galvanized steel occurred were explained by Britton on the basis of failure of the water to lay down a calcareous film. This was in accord with the opinion of Baylis[2] that the true function of a zinc coating was to afford temporary protection to the

iron or steel while the more permanently protective calcium carbonate film was formed. Both Baylis and Britton, therefore, attributed rapid failures primarily to the absence of calcareous films.

Schikorr's publication,[3] in 1939, of data showing that under certain conditions zinc actually could become cathodic to steel, shed an entirely new light on the problem of galvanized steel corrosion. He reported only a few tests which indicated that in Berlin water zinc became cathodic to steel after a short exposure above 60° C (140° F). Roters and Eisenstecken[4] later reported that zinc could become cathodic to steel after a few weeks exposure even at room temperature, particularly if carbonates were added to the solution. In both cases the reversal was associated with ennoblement of the zinc potential due to the formation of a dense film or layer of zinc corrosion product.

Extensive laboratory tests by Kenworthy and Smith[5] confirmed the fact that in certain solutions heated daily to 85° C (185° F) zinc did not electrochemically protect the bared steel edges of galvanized steel sheets. They concluded that in hot water "the zinc fails to give any appreciable protection to exposed steel" and emphasized the need for continuous zinc coatings. For best performance of zinc coatings they recommended that the free CO_2 be kept below 5 ppm and the hardness over 100 ppm as $CaCO_3$. Although they indicated having made electrode potential measurements no such data were reported.

In a fifteen-year test conducted with Baltimore water, pitting of galvanized pipes carrying hot water was deeper than that of black iron pipes.[6] This fact, together with the observation that zinc coating remained after 15 years, was taken as evidence that the galvanizing was cathodic to the base steel. Other observations made in service tend to confirm the reversal in potential;[7] however, it generally is difficult to draw definite conclusions because of incomplete information regarding the details of such service.

Only one publication, a very recent paper by Gilbert,[8] deals in any detail with the effect of electrolyte composition on the phenomenon of reversals in the zinc-steel couple. Gilbert reported that, in the absence of oxygen, zinc remained anodic to steel at temperatures up to 85° C (185° F). In aerated solutions he found that a temperature of over 60° C (140° F) was necessary to cause reversal, the reversal being due to ennoblement of the zinc. Upon cooling below 60° C the zinc usually again became anodic to the steel. In a few instances, as in a borax-boric acid buffer solution, the zinc remained cathodic down to room temperature. Also, samples continuously immersed at 85° C (185° F) for two months retained their noble potentials upon cooling. Gilbert attributed the noble potentials observed over 60° C to the formation of zinc oxide at these temperatures and the anodic potentials at lower temperatures to the formation of zinc hydroxide. A possible explanation offered for the retention of noble potentials upon cooling to room temperature was that all the zinc hydroxide nuclei had been converted to zinc oxide. Gilbert made preliminary tests on synthetic KCl and K_2SO_4 solutions and concluded:

> "It appears that chloride and probably sulfate ions can penetrate the film causing highly cathodic zinc electrode potentials, but that the presence of bicarbonate offsets the effect of chloride."

Although the occurrance of reversals between zinc and steel potentials is of basic importance in the corrosion of galvanized steel, this brief survey indicates that there is some disagreement as to the effect of temperature, and that very little has been done to determine the effect of electrolyte composition on the electrochemical behavior of zinc and steel.

Experimental

Composition of Test Specimens

The zinc used in this investigation was of high purity, analyzing 0.0017 percent iron, 0.0017 percent lead, 0.0006 percent cadmium, and 99.996 percent zinc (by difference). The steel was obtained by stripping the galvanized coating from commercial ⅜-inch galvanized steel pipe, and contained 0.08 percent carbon, 0.35 percent manganese, 0.093 percent phosphorous, 0.024 percent sulfur, a trace of copper, and 0.01 percent nickel.

Preparation of Specimens

The zinc and steel specimens were mounted in Bakelite, as for metallographic polishing. Watertight electrical connections were made through the Bakelite with a brass rod which was threaded into the sample and then enclosed in a Synthane tube, as is illustrated step-wise in Figure 1. The zinc samples were ¾ inch in diameter having an exposed area of 0.443 square inches, and the steel samples had a cross sectional area of 0.16 square inches. Surface preparation consisted of abrasion with No. 1 emery paper,

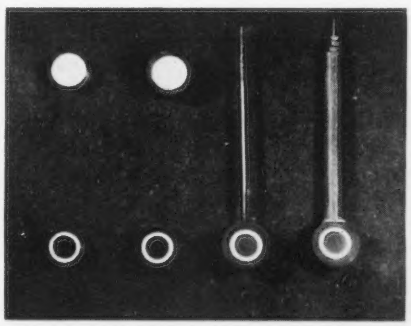

Figure 1—(Top) Bakelite mounting of zinc and steel electrodes.

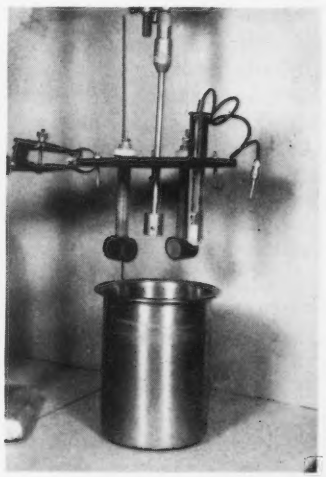

Figure 2—(Right) Experimental set up for current and potential measurements.

followed by a washing with distilled water and a rinse with acetone.

This technique was found to be very satisfactory, permitting uniform surface preparation and avoiding extraneous edge or waterline effects. Furthermore, it was possible to make repeated use of each sample, thus insuring uniformity of material throughout the series of experiments.

Electrolytes

In preparing the test solutions, the various salts were added volumetrically to distilled water from their respective stock solutions. The stock solutions were made with distilled water and reagent grade sodium salts (chloride, nitrate, sulfate and bicarbonate), and were analyzed in accordance with the procedures given in the Fifth Edition of *Scott's Standard Methods of Chemical Analysis.*

Analyses were made for pH, and for carbonate and bicarbonate concentration at the completion of each test. The initial pH of the test solutions varied depending on the composition of the electrolyte, but the pH after six hours of testing usually was in the range of 8.5 to 8.9, corresponding approximately to the pH of a saturated zinc hydroxide solution. Since very little zinc corrosion would be necessary to saturate the metal-liquid interface with zinc hydroxide, it was assumed that the pH of this interface was about 8.8 during most of the test and was more constant than the bulk pH of the electrolyte. The carbonate concentration was usually less than 5 ppm, so only total alkalinity as ppm bicarbonate has been reported.

Procedures

Beaker Tests

The experimental setup is shown in Figure 2. Covers for liter beakers were made from masonite, which supported the samples and the reference electrode used for potential measurements. Uniform agitation was produced by Sargeant Centrifugal Agitators (S-76695) rotated at 650-700 rpm. As shown in Figure 2 the samples were positioned below the stirrer so the solution centrifugally ejected from the stirrer did not impinge on the exposed surface.

In conducting the tests, the electrolyte was preheated to the given temperature and added rapidly to the test beaker which then was placed in a constant temperature bath. In this way it was possible to make current or solution potential measurements on the specimens within a few minutes after they were exposed to the electrolyte at the proper temperature.

Solution Potential Measurements

Leeds and Northrup saturated calomel electrodes (STD 1131-B) were used as reference electrodes for all potential measurements. A Model H Beckman pH meter was used for measuring voltages, and a standard cell was incorporated in the measuring circuit to increase the range of the meter to 1.50 volts. By checking the vacuum tube voltmeter against a Leeds and Northrup type K-2 potentiometer it was found that the voltage readings were accurate to within plus or minus three millivolts. The reference electrodes were checked against an auxiliary reference electrode before and after tests and were usually constant to within 5 millivolts. The potentials of duplicate samples in the same electrolyte usually agreed to within 10 millivolts.

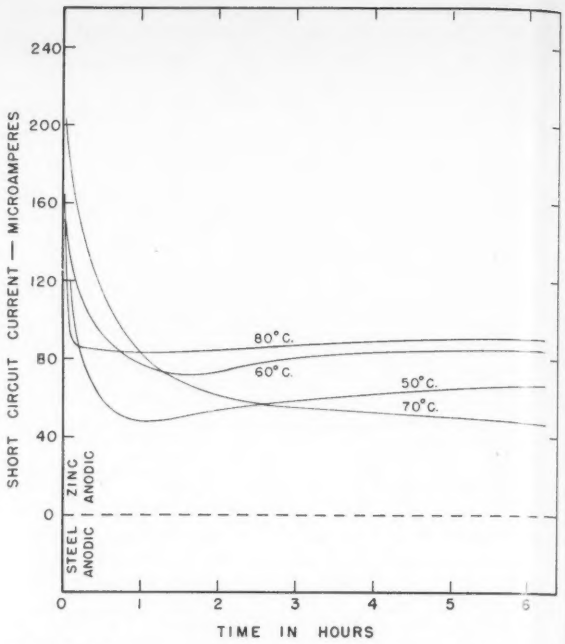

Figure 3—Effect of temperature on short circuit current of zinc-steel couple. Solution composition: 40-55 ppm HCO_3, 10 ppm SO_4, and 10 ppm NO_3 (sodium salts added to distilled water).

Current Measurements

The short circuit current measurements were made on the 0.5 milliampere scale of a Weston DC Milliameter, Model 622, serial No. 8720. The resistance of the meter on this scale was 80.06 ohms, certified by the manufacturer on August 7, 1947. A shunted double-pole double-throw toggle switch was used to insure continuous short-circuiting of the zinc-steel couples. The accuracy of any given reading was within 2.5 microamperes and the reproducibility from one test to another was usually within 10 microamperes.

Results

Effect of Temperature

In preliminary tests using oxygen-free solutions it was found that zinc remained strongly anodic to steel at all temperatures. This is in agreement with the findings of Gilbert. When the tests were conducted in open beakers with the electrolyte essentially saturated with air however, the zinc did not always remain anodic to the steel and it was under these conditions that subsequent tests were conducted.

The effect of temperature was investigated first by means of short circuit current tests in which the short circuit current in a zinc-steel couple was

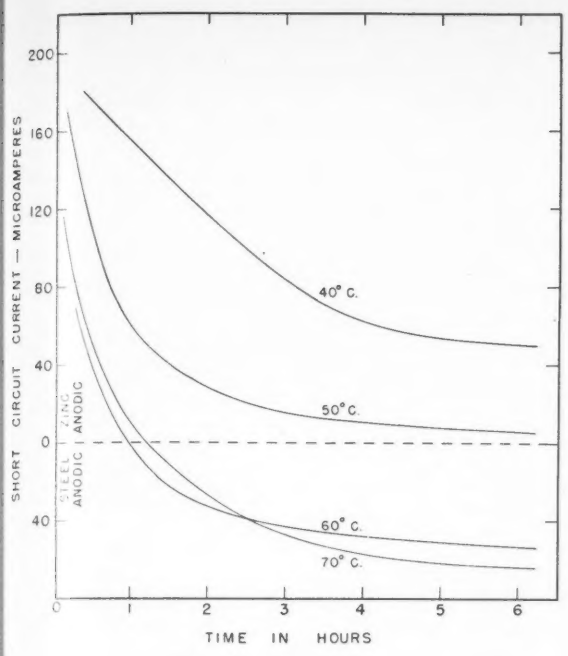

Figure 4—Effect of temperature on short circuit current of zinc-steel couple. Solution composition: 70-80 ppm HCO_3, 10 ppm SO_4, and 10 ppm NO_3 (sodium salts added to distilled water).

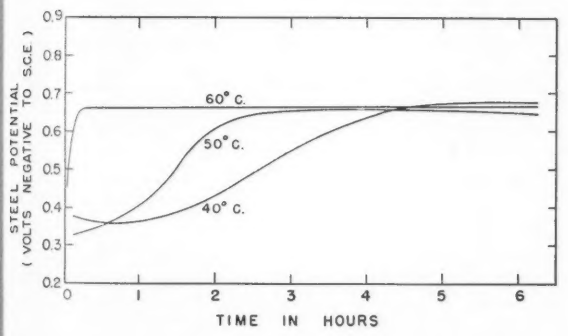

Figure 5—Effect of temperature on steel potential. Solution composition: 140 ppm HCO_3, 10 ppm SO_4, and 10 ppm NO_3 (sodium salts added distilled water).

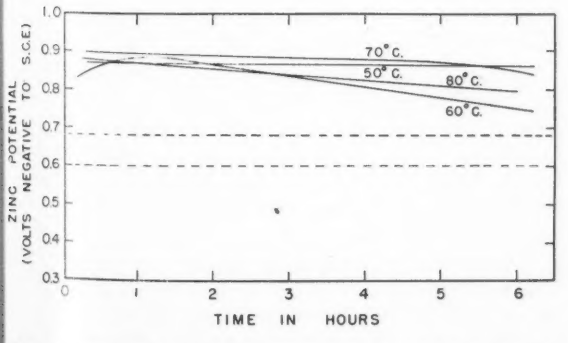

Figure 6—Effect of temperature on zinc potential. Solution composition: 15 ppm HCO_3, 10 ppm SO_4, and 10 ppm NO_3 (sodium salts added distilled water).

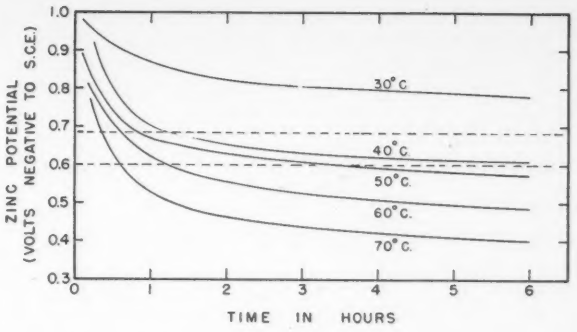

Figure 7—Effect of temperature on zinc potential. Solution composition: 115-140 ppm HCO_3, 10 ppm SO_4, and 10 ppm NO_3 (sodium salts added to distilled water).

measured as a function of time at different temperatures. The time-current curves presented in Figure 3 show that in a solution containing 40-55 ppmHCO_3, 10 ppm SO_4, and 10 ppm NO_3 (sodium salts added to distilled water) zinc remained anodic to steel during 6-hour tests even at a temperature of 80° C (176° F). When the bicarbonate concentration was increased to 70-80 ppm, however, reversals were obtained quickly at both 60° and 70° C (140° and 158° F) and were approached at 50° C (122° F) as is shown by the data plotted in Figure 4.

From these data, it is apparent that both temperature and electrolyte composition are important in determining the initial behavior of zinc-steel couples. In order to determine whether the reversal of potential was attributable to the steel or to the zinc, time-potential measurements were made on uncoupled steel and zinc specimens in similar solutions. The curves in Figure 5 show that the steady potential of steel electrodes was in the range of 0.6-0.7 volts, negative to a saturated calomel reference electrode, and that the only effect of temperature was to influence the amount of time necessary to reach the steady potential. As will be shown later, in Figure 15, steel potentials of this order of magnitude were observed even though the composition of the electrolyte was varied over wide limits. This range of steel potentials has been indicated with dotted lines in subsequent graphs for comparison with potentials of zinc electrodes.

For zinc, however, the potentials were found to vary widely depending on the temperature and the electrolyte composition. In a solution containing 10 ppm NO_3, 10 ppm SO_4 and only about 15 ppm HCO_3 relatively anodic potentials were obtained at all temperatures, Figure 6. Upon increasing the bicarbonate ion concentration to 115-140 ppm, however, the zinc potentials were much more cathodic especially at the higher temperatures, Figure 7.

These data show that the reversals observed in short circuited zinc-steel couples may be attributed to changes in the zinc potential. A comparison of the data in Figure 6 and 7 would indicate that the cathodic zinc potentials are associated with high bicarbonate concentrations, and in such solutions become progressively more cathodic as the temperature is

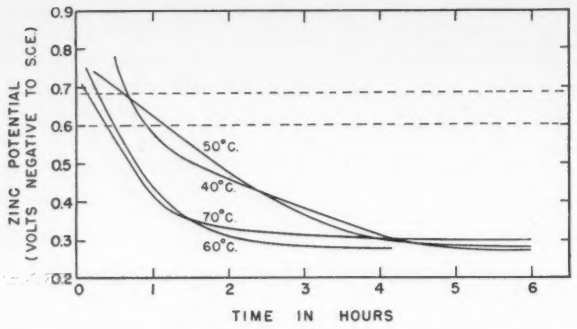

Figure 8—Effect of temperature on zinc potential. Solution composition: 35-45 ppm HCO_3, and 5 ppm NO_3 (sodium salts added to distilled water).

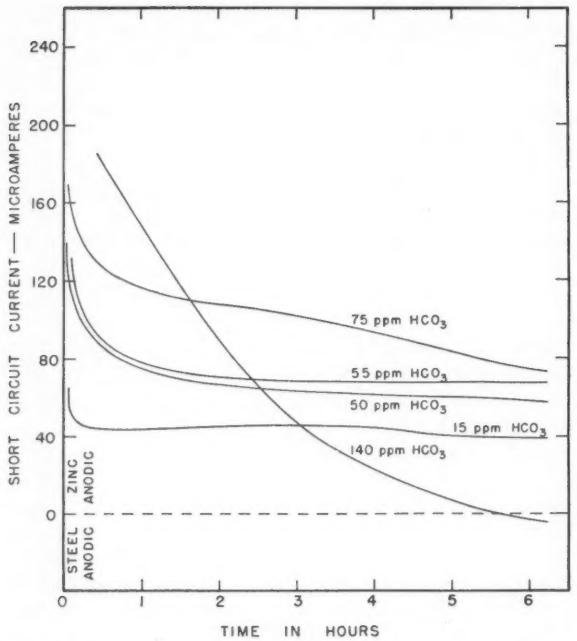

Figure 9—Effect of bicarbonate concentration on short circuit current of zinc-steel couple at 60° C. Solution composition: 10 ppm SO_4 and 5 ppm NO_3 (sodium salts added to distilled water).

increased. That this is not the complete story is shown by the data plotted in Figure 8 showing the time-potential behavior of zinc electrodes in a solution containing only 35-45 ppm HCO_3 and 5 ppm NO_3. These data show that it is possible to obtain very cathodic zinc potentials even at low temperatures in certain solutions. A reversal was obtained in the current flow of a zinc-steel couple in this particular electrolyte containing both nitrate and bicarbonate but no sulfate or chloride in less than six hours even at 30° C (86° F).

The data presented thus far confirm the results of previous investigators insofar as they associated reversals in zinc-steel couples with cathodic zinc potentials. Previous reports that this was solely a temperature effect are not acceptable, however, and

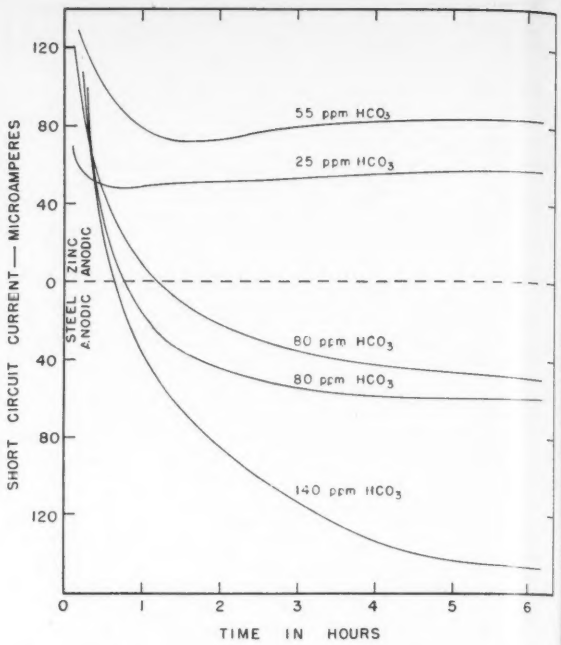

Figure 10—Effect of bicarbonate concentration on short circuit current of zinc-steel couple at 60° C. Solution composition: 10 ppm SO_4 and 10 ppm NO_3 (sodium salts added to distilled water).

additional data have been obtained to illustrate the effect of electrolyte composition.

Effect of Electrolyte Composition

Plotted in Figures 9 and 10 are time-current curves of zinc-steel couples at 60° C (140° F) showing the effect of variation in bicarbonate concentration in a solution containing 10 ppm SO_4 and 5 ppm and 10 ppm of NO_3, respectively. In both cases reversals were obtained more quickly at the higher bicarbonate concentrations, whereas at intermediate concentrations the amount of current flowing with zinc as an anode was increased.

That the presence of sulfate and/or chloride decreased the reversal tendencies is shown by the time-current curves in Figures 11 and 12. The dotted curve in the latter figure is for a solution containing 10 ppm SO_4 but no chloride, indicating that sulfate additions are much more effective than chloride additions in repressing the reversal.

The effect of nitrate additions was found to be opposite to the effects of chloride and sulfate, namely nitrate additions even in small amounts promoted reversals in zinc-steel couples as is shown by the time-current curves of Figures 13 and 14.

To further elucidate the effects of electrolyte composition, additional potential measurements were made on uncoupled zinc and steel specimens. The potential of steel, as suggested above, was found to be independent of electrolyte composition as shown in Figure 15. As was expected, the zinc potentials varied over wide limits depending on the electrolyte composition. The addition of progressive amounts of

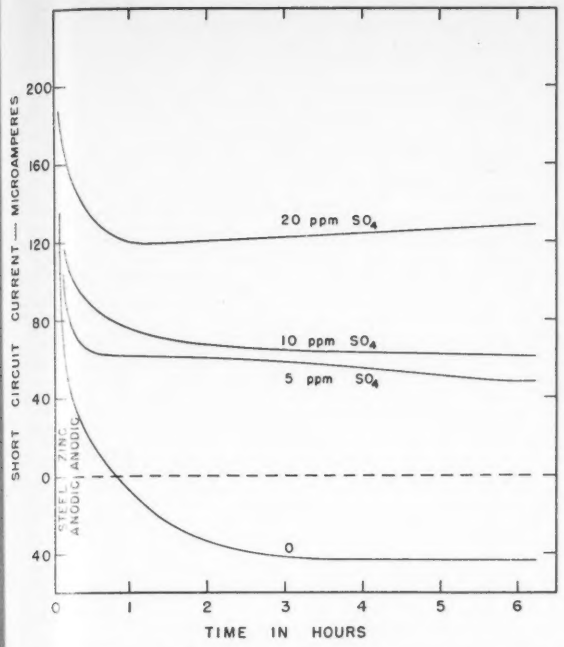

Figure 11—Effect of sulfate concentration on short circuit current of zinc-steel couple at 60° C. Solution composition: 50-55 ppm HCO_3 and 5 ppm NO_3 (sodium salts added to distilled water).

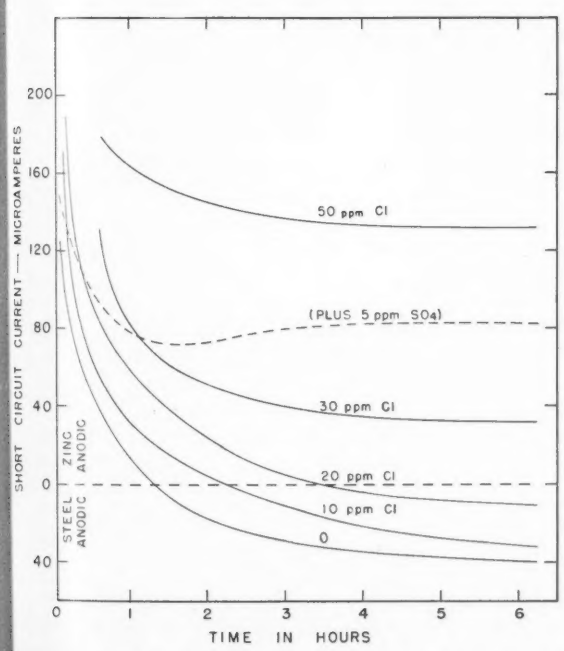

Figure 12—Effect of chloride concentration on short circuit current of zinc-steel couple at 60° C. Solution composition: 40-50 ppm HCO_3, 5 ppm SO_4 and 10 ppm NO_3 (sodium salts added to distilled water). Broken curve is for solution containing 10 ppm total SO_4 but no chloride.

bicarbonate caused progressively more cathodic zinc potentials as shown in Figures 16 and 17. With the addition of sulfate and chloride, progressively more anodic potentials were observed as shown in Figures 18, 19, and 20; and the opposite effects of nitrate additions are shown in Figure 21.

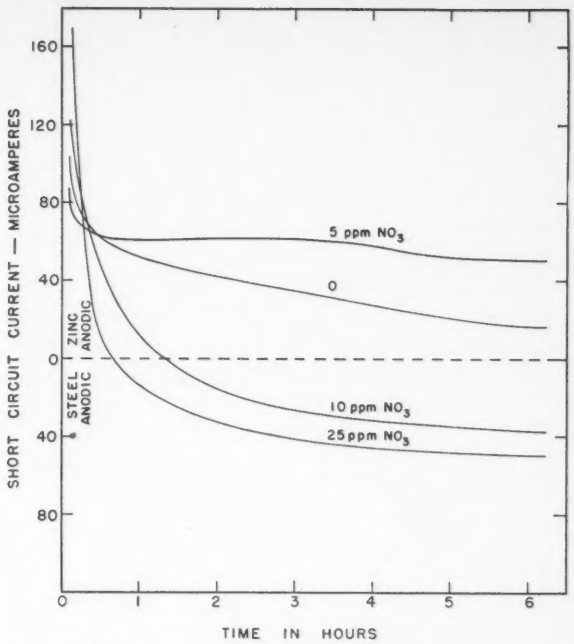

Figure 13—Effect of nitrate concentration on short circuit current of zinc-steel couple at 60° C. Solution composition: 40-55 ppm HCO_3 and 5 ppm SO_4 (sodium salts added to distilled water).

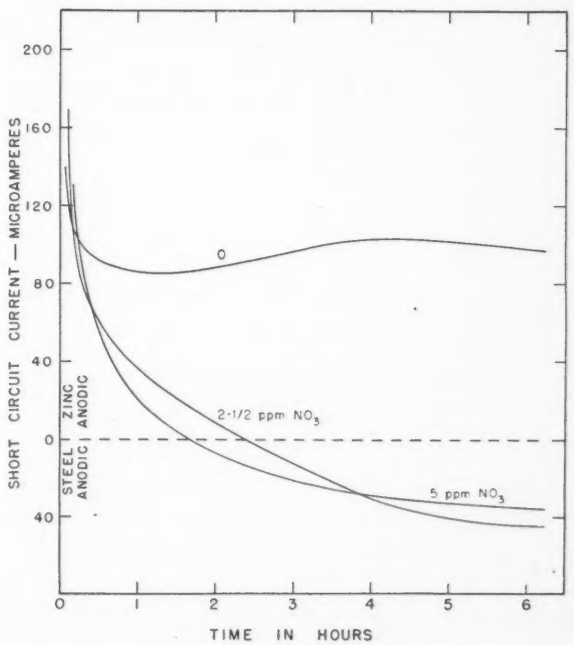

Figure 14—Effect of nitrate concentration on short circuit current of zinc-steel couple at 60° C. Solution composition: 65-75 ppm HCO_3 and 5 ppm SO_4 (sodium salts added to distilled water).

Discussion

Before discussing the above results in any detail it should be pointed out that the six-hour laboratory tests as conducted were not designed as accelerated tests which would predict long time behavior. Furthermore, investigations of many important variables

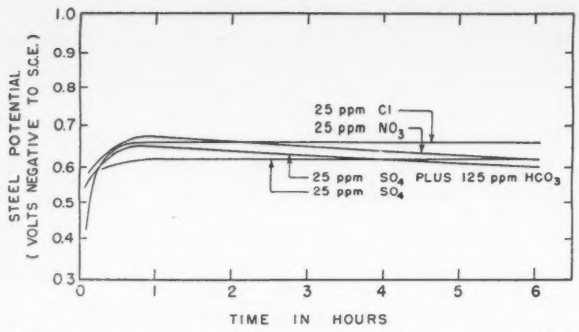

Figure 15—Effect of electrolyte composition on steel potential at 60° C. Solution composition: 15 ppm HCO_3 and additions as indicated (sodium salts added to distilled water).

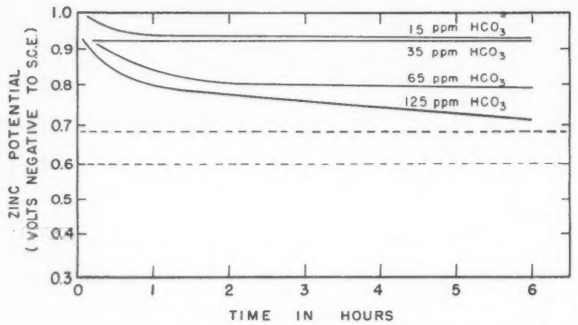

Figure 16—Effect of bicarbonate concentration on zinc potential at 60° C. Solution composition: 10 ppm SO_4 (sodium salts added to distilled water).

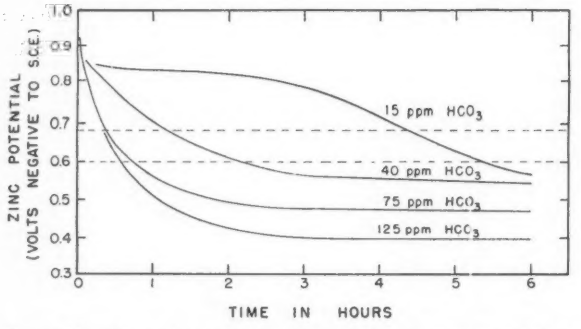

Figure 17—Effect of bicarbonate concentration on zinc potential at 60° C. Solution composition: 10 ppm SO_4 and 5 ppm NO_3 (sodium salts added to distilled water).

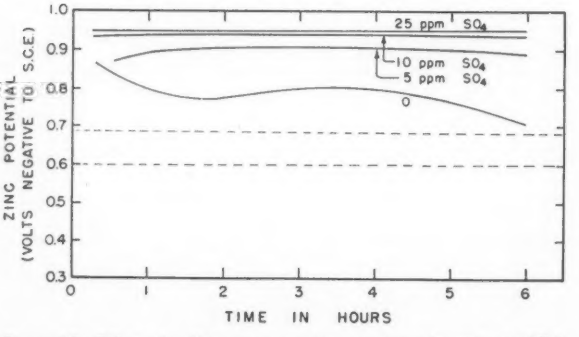

Figure 18—Effect of sulfate concentration on zinc potential at 60° C. Solution composition: 10-15 ppm HCO_3 (sodium salts added to distilled water).

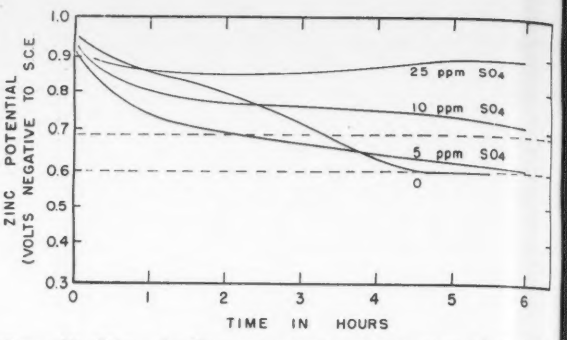

Figure 19—Effect of sulfate concentration on zinc potential at 60° C. Solution composition: 125-135 ppm HCO_3 (sodium salts added to distilled water).

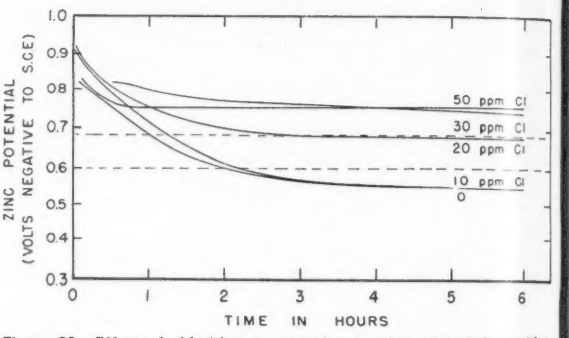

Figure 20—Effect of chloride concentration on zinc potential at 60° C. Solution composition: 40 ppm HCO_3, 5 ppm SO_4 and 10 ppm NO_3 (sodium salts added to distilled water).

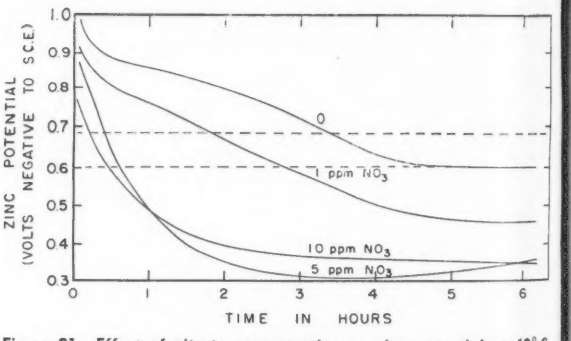

Figure 21—Effect of nitrate concentration on zinc potential at 60° C. Solution composition: 130-135 ppm HCO_3 (sodium salts added to distilled water).

of electrolyte composition, though now in progress, are not sufficiently complete for inclusion at this time. These tests were made as the first phase of an investigation which ultimately will include long-time tests of zinc and steel as encountered in actual galvanized steel. Therefore, considerable further work is considered essential before any predictions should be made regarding the corrosion of galvanized steel in natural waters.

That reversals were obtained in the potentials of zinc and steel electrodes, however, can not be disputed. Since these reversals appear to be associated primarily with the potential behavior of the zinc electrode, it is worthwhile to discuss this point in more detail. On a freely corroding zinc electrode,

anodic and cathodic reactions are occurring simultaneously, and the overall potential of the electrode is determined by the relative degrees of anodic and cathodic polarization associated with these reactions. The cathodic zinc potentials observed in certain solutions are quite satisfactorily explained by assuming that the local anodic reaction is sufficiently polarized that the overall potential is determined mainly by the cathodic reaction. On this basis qualitative interpretations can be postulated for the marked effects of electrolyte composition on the potential of zinc electrodes.

Effects of Chloride and Sulfate

Evans[9] associated the corrosive effects of chloride and sulfate on zinc with the solubility of zinc chloride and zinc sulfate, which he considered to be primary products at the anodic areas. This high solubility would deter the precipitation in situ of corrosion product at the anodic areas, thus decreasing the tendency for stifling of the anodic reaction. It also has been shown by Evans[10] that chloride and sulfate ions, particularly the former, are capable of penetrating metallic oxide films, thus causing an increased number of anodic sites on a corroding metallic surface. Such behavior on the part of chloride and sulfate would tend to increase the anodic areas and to depolarize the anodic reaction. Since both increased anodic area and anodic depolarization would result in more anodic zinc potentials, as actually was observed, such mechanisms well may constitute a partial explanation of the observed phenomena. They cannot be accepted as the complete explanation, however, for they do not adequately interpret the difference in the effects of chloride and sulfate additions. Chloride ions are considered to penetrate films more readily than sulfate ions, and zinc chloride is more soluble than zinc sulfate; yet sulfate additions are significantly more effective in shifting the zinc potential in the anodic direction.

In comparing the effects of sulfate and chloride ions on the corrosion of zinc, Evans also noted that the corrosion product in sulfate solutions was more adherent and less gelatinous than in chloride solutions. He explained this difference on the basis of special experiments showing that sulfate ions possess greater flocculating power for zinc hydroxide than do chloride ions. It may be postulated then that the resulting corrosion product film is more resistant to oxygen diffusion in the presence of sulfate than in the presence of chloride. Since the effect of oxygen is to depolarize cathodic areas, more cathodic polarization would be expected in the presence of sulfate, which in turn would be evidenced by more anodic zinc potentials. This explanation for the difference in the effects of sulfate and chloride additions is in accord with the precipitation behavior of metallic sols and may well be supplementary to the effects of chloride and sulfate additions on the anodic reaction.

Effects of Nitrates

Although Britton[1] considered the effects of nitrates to be similar to those of chloride and sulfate so far as zinc corrosion was concerned, the data presented above show conclusively that nitrate additions result in more cathodic zinc potentials. The most logical explanation is that, even in such dilute solutions, the nitrate ion acts as an oxidizing agent permitting easier discharge of electrons at cathodic surfaces. This cathodic depolarization would shift zinc potentials in the cathodic direction in agreement with observations.

Effects of Bicarbonates

Bicarbonate additions likewise cause a shift of the zinc potential in the cathodic direction. This is in accord with an earlier report by Roters and Eisenstecken[4] that carbonate additions promoted reversals. Gilbert[8] also stated that bicarbonate addition counteracted the effects of chloride and sulfate on zinc potentials. So far as zinc corrosion rates are concerned, Kenworthy and Smith,[5] using various waters and temperatures, found that the attack on zinc was increased in all cases by increasing the carbon dioxide concentration.

The observed cathodic potentials and the increased total corrosion both can be explained on the basis of increased cathodic depolarization accompanying increased bicarbonate concentration. Cathodic depolarization involves the discharge of electrons through the reduction of some constituent such as hydrogen ion, dissolved oxygen, or some other oxidizing constituent. The hydrogen ion concentration of the solution could not be increased by the addition of sodium bicarbonate, nor could the dissolved oxygen. It is conceivable that in the presence of bicarbonate the structure of the corrosion product may be such as to permit more ready diffusion of the available oxygen, but this explanation is not entirely satisfactory. Furthermore, it is difficult to consider the bicarbonate ion, per se, as a relatively strong oxidizing agent. There is strong evidence, however, from polarographic data that the bicarbonate ion does combine with hydrogen peroxide to form unstable percarbonic acid which is an oxidizing agent.[11] That hydrogen peroxide is formed during the aqueous corrosion of several metals, particularly zinc, long has been known.[12] Polarographic data also show that the cathodic reduction of oxygen to water is a two-step process with hydrogen peroxide being an intermediate.[13]

It is possible, therefore, that the reason bicarbonate acts as such an effective cathodic depolarizer for zinc in aerated solutions is that bicarbonate and hydrogen peroxide combine to form percarbonic acid, which gives more effective cathodic depolarization than do the oxygen and hydrogen peroxide in the absence of bicarbonate.

Effect of Temperature

In his recent publication on the behavior of zinc-steel couples, Gilbert found that a temperature of over 60° C (140° F) was necessary to cause a reversal; however, once obtained, the reversal occasionally persisted even after the solution was cooled. In explanation of his observations, Gilbert favored

the theory of Grubitsch and Illi[14] to the effect that zinc oxide was formed at higher temperatures and zinc hydroxide at lower temperatures. Gilbert then proposed that zinc oxide gave rise to noble potentials; zinc hydroxide, to anodic potentials; and that in the few cases where cathodic potentials were retained on cooling, the zinz hydroxide nuclei all had been converted to zinc oxide by the long exposure at the higher temperature.

It is difficult to reconcile Gilbert's explanation with either the data reported above, or with Roters' and Eisenstecken's observation that zinc-steel couples occasionally reversed after a few weeks' exposure at room temperature. The data presented above indicate that electrolyte composition must be taken into account in disussing the effect of temperature. Nitrate additions give rise to cathodic zinc potentials over the temperature range of 30° to 70° C (85° to 158° F). The ennobling effect of bicarbonate becomes greater as the temperature is increased, and it is believed that this accounts for the fact that most previous investigators have observed reversals only at elevated temperatures. The increased effectiveness of bicarbonate for the cathodic depolarization of zinc is gradual with temperature, and there is no indication of marked change in the temperature range of 50° to 60° C (122° to 140° F) as there would be if the zinc potential were determined by a transition of zinc hydroxide to zinc oxide in this region. One possible explanation for the increased effectiveness of bicarbonate at elevated temperatures is that the stability of percarbonic acid is decreased with temperature. Another possibility is that the increase is due merely to the increased rate of the controlling reaction in the step-wise reduction of oxygen to water.

It is apparent that temperature is often a factor in determining the potential of zinc and is therefore of importance in considering reversals of zinc-steel couples. Whether or not reversals will occur at a given temperature depends, however, on the composition of the water. It has been found that increasing the temperature increases the probability of reversal in waters where the reversal is due to bicarbonate, but has little or no effect in waters where the reversal is due to nitrate.

Conclusions

Reversals were obtained in zinc-steel couples under laboratory conditions. In accordance with the findings of previous investigators, these reversals were attributed to changes in the potential of zinc specimens.

Whether or not cathodic zinc potentials are obtained depends on both electrolyte composition and temperature. Of these factors, electrolyte composition is the more important. In the absence of oxygen no reversals were observed even at elevated temperature. Of the variables studied in the presence of oxygen, sulfates and chlorides decrease whereas bicarbonates and nitrates increase the probability of reversal. In border-line solutions, increasing the temperature appears to increase the probability of reversal.

Research is being continued with particular attention to the effect of long exposure time and of the complex conditions encountered in natural waters.

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DISCUSSION

By F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.

Experience in Arkansas oil fields confirms Mr. Hoxeng's and Mr. Prutton's ideas on the effect of carbon dioxide in causing reversal of the zinc-iron couple. Wells producing gas containing 3 to 20% CO_2 produced the corrosion shown in the accompanying photograph of galvanized 3″ tubing. The bottom hole temperature is about 100° F and the water produced has the following analysis:

Total solids	72,000 ppm
Na and K	22,070
Ca	4,224
Mg	943
Cl	43,900
HCO_3	185
SO_4	29
Br	611

The iron corrosion product is siderite ($FeCO_3$)

Corrosion on 3-inch galvanized tubing exposed in an oil well. The grooves around the zinc had a maximum depth of 0.03 inch. (Length of exposure unknown. This was not an experimental installation.)

Deterioration of Steel Sheet Pile Groins At Palm Beach, Florida*

By CULBERTSON W. ROSS

IN HIS BATTLE to hold the sand on beaches, the engineer has evolved the groin as a protective structure. Groins are structures built out from the shore to reduce or prevent the motion of sand along the beach. Their purpose is to hold the sand that is on the beach and to accumulate more sand from any that may be drifting along the shore. Groins resemble small jetties; they may be built of wood, concrete, stone or steel. This article will describe tests made at Palm Beach, Florida, to determine the reason for the rapid deterioration of steel groins at this location.

The project was a cooperative effort by The Beach Erosion Board, the Jacksonville District of the Corps of Engineers, the city of Palm Beach and five steel producing companies: Carnegie, Bethlehem, Jones and Laughlin and Inland steel companies of the United States, and the Larssen Company of Germany.

CULBERTSON W. ROSS

The author of papers on thermal expansion of brick and prestressed concrete pipe, Mr. Ross is a civil engineer doing research on structures at the Beach Erosion Board, Office of Chief Engineer, Department of the Army, Washington, D. C. Prior to 1946 he was with National Bureau of Standards doing research in masonry. He is a graduate of the University of Michigan.

Location and Exposure at Palm Beach

Palm Beach is on the east coast of Florida, about 120 miles from the southern end of the state. It is on a barrier beach which is chiefly sand. The beach sand consists of about 64 percent limestone and shell and 36 percent silica.

Strongest winds are from the northeast. The fetch, or the distance which waves may travel before striking the beach, is about 100 miles towards the east and southeast, to the Bahama Islands. The beach is open to the ocean on the northeast. The mean tide range is 2.8 feet. The area is subject to occasional tropical cyclones which throw violent waves against the beach and produce fluctuations of the water level as great as 7 feet. Two such storms occurred during the test period, in 1941 and again in 1944.

Along the east coast of Florida, there is a strong drift of sand from north to south which is caused by the action of waves which strike the beach predominantly from a direction north of east. The uprush and backwash of the waves moves the sand southward in a zigzag path. While there are temporary and seasonal reverses of this direction of the sand drift—which is called "littoral drift,"—the average drift of sand to the south is estimated to be 225,000 cubic yards per year.

Two 320-foot jetties were built in 1928 to improve Lake Worth Inlet, at the north end of Palm Beach. There was a large accretion of sand north of the jetties and severe erosion south of them. In an effort to hold the beach and to prevent the washing away of large areas of valuable land, a system of groins was built. After a few years, large holes developed in the steel piles of which the groins were formed.

Description of the Groins

Five experimental groins were built during 1937 by the city of Palm Beach of steel piles contributed to the Beach Erosion Board by the steel companies. The groins are located between 2500 and 6500 feet south of Lake Worth Inlet. The length of the groins varied from 128 feet to 201 feet. Groins 139-N, 135-N and 121-N were built of deep-arch piles and groins 131-N and 112-N were built of straight section piles. These numbers refer to the location of the groins on the beach. The nominal thickness of the steel of groin 112-N was 0.547 inch and of the others 0.375 inch. Four of the groins were built of standard structural rim steel containing less than 0.05 per cent copper, but the other groin, 112-N, was built of steel containing 0.35 per cent copper. The piles of groin 112-N had been painted with a shop coat of black paint when received, and a number of the piles of groin 139-N were covered by an assortment of commercial marine paints and special coatings. Groin 121-N was sheathed with 2-inch creosoted timber planks for 65 feet of its length.

Types of Exposure of the Steel

Four types of exposure were studied: atmospheric,

*A paper presented at the Fifth Annual Conference of The National Association of Corrosion Engineers at Cincinnati, Ohio, April 11-14, 1949.

Figure 1—Serious structural deterioration of a groin at Palm Beach, Fla., after 12 years' exposure. The marine life, sabellaria, may be noted.

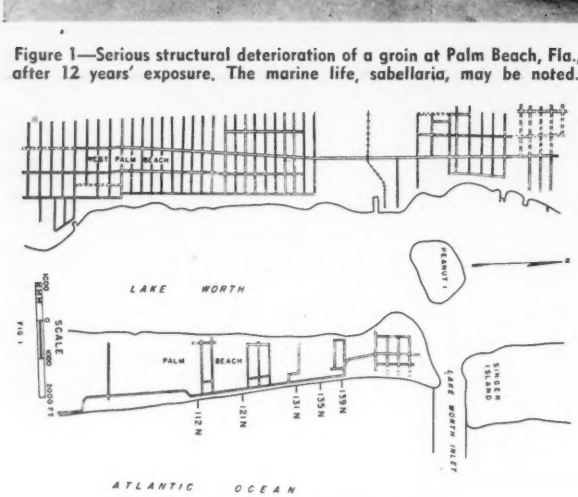

Figure 2—Location of experimental groins.

subsand, wetting-and-drying, and sand abrasion. Each type of exposure was found in each of the four groins.

Atmospheric exposure is represented by the part of the groin near the shore which rises above the sand and is exposed to the action of the atmosphere and salt spray carried by the air from the waves breaking on the beach nearby. Waves reach this elevated part of the groin only during storms.

Subsand exposure is represented by the part of the groin below the sand level. The steel is buried by the sand and is in contact with salt water and air in the sand.

Wetting-and-drying exposure is represented by the outer end of the groin between high and low water, where the steel is subject to wetting and drying because of wave and tide action.

Sand abrasion exposure is represented by the area of the groin just above the sand line on that part of the beach which is subject to the action of ordinary waves. Here, sand is thrown into suspension and carried shoreward by the breaking waves. As the water recedes, a carpet of sand is carried along the bottom. During storms, a much larger area of the groins may be subject to scour by sand in suspension. However, storm periods are infrequent at this location.

The identical area of the groins may be subject to several types of exposure at different times, because waves frequently change the position of the sand line.

Observations

The Jacksonville District of the Corps of Engineers made 39 inspections of the groins during the period 1937 to 1946. At each inspection the position of the sand line along the sides of the groins was determined by measurements at every 10 feet. The condition of the piles, paint, and timber sheathing was observed. The location of the first holes and the time of their appearance also was determined.

Measurement of the Thickness of the Steel

The Beach Erosion Board measured the thickness of the piles in 1940, 1942 and 1946. In 1940, the thickness of the steel in each groin was measured at three points: near the shoreward end of the groin above the sand, where subject to atmospheric exposure; near the sand line where the waves were breaking, representing sand abrasion exposure; and towards the outer end of the groins between the high and low tide lines, representing wetting-and-drying exposure. The same fifteen areas were measured again in 1942 and 1946, even though changes of the sand line had made changes in their exposure.

The measurement of each area consisted of drilling one hole in each of 5 piles, and making eight measurements with a small micrometer of the thickness of the steel around the hole. The average of the 40 measurements was taken as the thickness of the steel at any one area. New holes were drilled several inches from the old holes for the measurements made in later years.

Treatment of Data

Inasmuch as the exposure of the areas varied from inspection to inspection, effort was made to compute the proportion of time during which each area was subject to a specific type of exposure. Atmospheric, subsand, and wetting-and-drying types of exposure were indicated by the position of the sand line at each inspection. The groin area subject to sand abrasion was considered arbitrarily to extend from 0.2 foot below the sand line to 0.6 foot above the sand line. It was assumed that conditions found at the 39 inspections were representative of interim conditions.

Rates of loss in thickness of steel were found for the various types of exposure from the proportion of time the measured areas were subject to the different types of exposure, and from the total loss in thickness of the piles. There were some inconsistencies in the data. Perhaps these resulted from the necessity of drilling the new holes at points where the original thickness or the rate of corrosion may have been different. Perhaps the number of inspections made was not large enough to determine accurately the proportion of time for the various types of exposure. However, because of the large number of measurements made, and the number of areas measured, it is believed that the values for the rates of loss of thickness for the different types of exposure are of the correct order of magnitude.

The average rate of loss of thickness of the steel when covered on both sides by sand was found to be

0.001 inch per year; when exposed to the atmosphere, it was 0.011 inch per year; when exposed to wetting-and-drying, it was 0.005 inch per year; and when in the abrasion zone, it was 0.117 inch per year.

Another method of determining the rate of loss of steel was to note the time of the appearance of holes. A hole indicates zero thickness for that area. From the exposure record previous to the appearance of the hole, the rate of loss of thickness of the steel is computed. From the data for the areas where holes appeared, average yearly rates of loss from 0.049 inch to 0.094 inch were found for the different groins. If the proportion of time of exposure to sand abrasion is considered, a value of 0.373 inch per year is found for this type of exposure. This value is higher than the value found from the measured areas and indicates that the erosion was much more severe in the areas where the holes appeared. These areas may have been located near the point where the waves broke most frequently. This value of 0.373 for the rate of loss when exposed to sand abrasion indicates that a ⅜-inch steel pile would be perforated in about one year if the sand line remained at the same level on both sides of the groin.

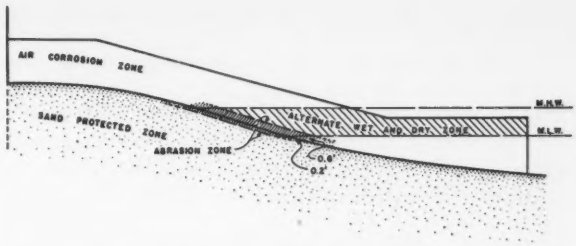

Figure 3—Conditions of groin exposure.

Figure 4—Holes at the sand line, Groin 139N after 5.3 years' exposure.

Discussion

There were other evidences of sand abrasion in addition to the high rate of loss of thickness. The steel frequently appeared bright and polished at the sand line. Paint had disappeared from the piles in bands parallel to the sand line within 3 months after the groins were built. Most of the paint was gone from the visible portion of the piles within 6 months after installation. The force of sand erosion also was observed in piles which developed large holes near the sand line while their steel tops retained almost their original thickness.

The low rate of loss of thickness of the steel under subsand exposure indicates that an abundant sand supply which would keep the groin covered most of the time would greatly extend the life of a groin. Groins, however, seldom will be built on beaches that are well supplied with sand, and in their function of retaining and accumulating sand will be exposed, at least in part, to the abrasive action of waves and sand.

The 2-inch timber sheathing which was placed over parts of groin 121-N gave good protection against abrasion as long as the sheathing remained in good condition. About nine years were required for the perforation of this groin, as compared with only four years for perforation of similar unsheathed groins. The time required for perforation might have been extended even more if the sheathing had been replaced after five years.

Groin 112-N differed from the others in that its piles contained 0.35 percent copper and were 0.547 inch thick instead of 0.375 inch. Here, holes first appeared in about 11 years. The longer period to perforation is believed to be chiefly a result of the greater thickness of the steel. The chance that the sand line will remain long enough in one place to perforate the groin is reduced by the greater thickness of the steel. The rates of loss of thickness at the measured areas were as high for this groin as for similar areas in other groins. Apparently the copper content did not improve the behavior of the steel.

Groin 131-N was built of straight section piles instead of arch section piles. It required 4.8 years for perforation instead of the 4.2 years required for perforation of groins built of arch section piles of the same thickness. It would appear, as might be expected, that abrasion was more intense on the arch section piles, inasmuch as they obstruct the flow of waves more than the straight section piles. However, the difference in the time required is not large enough to be very significant.

Conclusions

The rapid deterioration of the steel groins at Palm Beach was caused by the abrasive action of sand carried by the waves. Abrasion is most intense for an inch or two above the sand line but is spread over a wider area by changes in the position of the sand line. The abrasion removed the rust from the piles and permitted rapid corrosion of the exposed steel.

Groins built of ⅜-inch steel piles were perforated in 4.2 years, showing an average annual loss of thickness of 0.094 inch. However, during the period in which an area is subject to the abrasion of waves and sand, a yearly rate of loss as high as 0.373 inch is indicated. At this rate, a pile of ⅜-inch steel would be perforated in about one year, provided there was no change in the position of the sand line.

The rates of loss in steel thickness of the parts of the groin not exposed to sand abrasion are relatively moderate, being about 0.011 inch per year for atmospheric exposure, 0.005 inch per year for wetting-and-drying exposure, and 0.001 inch per year for subsand exposure. The time required for the perforation of

⅜-inch steel would be respectively 34 years, 75 years and 375 years.

Various paints and coatings used on the piles soon were removed by the waves and sand erosion and were therefore ineffective in protecting the steel.

A two-inch timber sheathing placed over the groin gave protection against abrasion as long as the sheathing remained in good condition, for about 5 years.

The use of steel piles with a thicker section may well give a longer life for the groin which is more than proportional to the added cost.

Holes appeared in two groins constructed of ⅜-inch arch section piles in 4.2 years; in a groin constructed of ⅜-inch straight section piles in 4.8 years; in a groin constructed of ⅜-inch arch section piles protected by wood sheathing in 9 years; and in a groin constructed of 0.547 inch straight section piles containing 0.35 percent copper in 11.1 years. It may be remembered, however, that these periods do not represent the life of the groins. They will continue to function as groins for a number of years after the appearance of the first holes with gradually decreasing efficiency.

This paper is a summary of "Experimental Steel Pile Groins, Palm Beach, Florida," Technical Memorandum No. 10, published by the Beach Erosion Board.

Technical Factors in Testing Pipe Line Coatings★

By D. E. STEARNS, M. W. BELSON* and ROBERT H. LEE**

OVER 100 YEARS ago in the book "Two Years Before The Mast," Dana wrote of the holyday." His reference was to the application of tar to the ship's rigging as a protection against the sea water. The term "holiday" has carried over to general use in the pipe line industry, retaining its original meaning, as a defect in the coating.

The many reasons for applying protective coating to underground steel pipe are so generally recognized that it is unnecessary to mention them here. The years of work and experience with pipe line coatings have greatly improved their protective value. However, in spite of the improvements in materials, machines and techniques of application, the holiday has continued to occur . . . to a lesser extent, of course, but they are still in there behind the coating gang.

Pipe line coating material must resist penetration by moisture, and must be electrically non-conductive in order to prevent flow of current between the pipe and the earth. The material must therefore be a dielectric, and its protective value is a function of its merit as a dielectric.

In the early days of pipe line coating applications inspection was purely visual, sometimes aided by use of a mirror to more readily observe the under side of the pipe. Since considerable current may flow through defects completely invisible to the eye, it became apparent that visual inspection was not adequate. One of the first attempts at electrical inspection was the use of a cloth soaked in salt water and connected to a battery through a milliammeter. The cloth was pulled over the surface of the coating. A change in reading of the milliammeter indicated a holiday somewhere under the cloth. The remaining problem was to find where. This, of course, was a slow, tedious job which was highly impractical. In the early 30's a Ford spark coil was used in conjunction with a wire brush or broom to sweep over the coating. This was followed by use of gasoline engine-driven generators and many adaptations of auto ignition systems. All of these methods depended on the sight or sound of the spark to indicate a holiday. The thoroughness of inspection depended entirely on the attention given the job by the operators of the inspection equipment. Today, detectors are available which give both a visible and audible signal to the inspector whenever a holiday is encountered. The latest equipment also incorporates other features in its design which are the result of many years of experience, research, and development.

The minimum voltage at which adequate inspection may be made is determined by the mechanics of applying the coating, and by the thickness of coating. As an example, a commonly used coating consists of enamel followed by one or more wraps of other materials, such as glass fibre, impregnated felt or the like, and kraft paper. The wrapping materials will have overlaps and may have occasional wrinkles. Thus, the total thickness of material placed on the pipe may be as much as 5/32 inch in random areas. The minimum inspection voltage should be that which will jump an air path equal to the distance through the thickest section of the coating. A voltage impressed across an insulating wrap consisting of several different materials will divide itself across

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each layer as a function of the thickness of each layer, and in inverse proportion to the dielectric constant of the material. Air has a dielectric constant of approximately 1. Coal tar enamel has a dielectric constant of about 2. Thus, if 3,000 volts are impressed across ⅛" of air and ⅛" of enamel, the voltage will be divided between the air and the enamel in a two to one ratio, with 2,000 volts impressed on the air gap and 1,000 volts on the enamel. In this instance the ⅛" air gap is sufficient to withstand the full 3,000 volts without sparkover. Thus a proper test would not be applied to the coating. The voltage must be high enough to bridge any air gaps, such as small depressions or bubbles in the coating, so that the full testing voltage is impressed across the material on which the test is desired. A voltage wave having a crest value of 10,000 volts will jump an air gap of 5/32" between suitable spheres. This same voltage will jump over three times this distance between needle points. Since commercial electrodes have sharp edges or points, and the diameter of the wire in the electrode is small compared to the gap between electrode and pipe, and since, further, the pipe itself is rough, the sparkover distance between electrode and pipe is between that with needles and with spheres. Thus, on pipe coatings having a maximum spacing between pipe and electrode of 5/32", a minimum test voltage of 10,000 crest volts is satisfactory from the distance standpoint. By a similar reasoning, a minimum test voltage of 30,000 is required to inspect coatings that may be up to ½" thick.

It should be noted here that when voltage is impressed at a point on the surface of the coatings, the coating for a considerable area around the point is subjected to nearly the same stress. This is because of the creepage factor. The surface of the coating will conduct current to a small degree. Further, the stress placed on the air in the vicinity of the electrode is sufficient to ionize it for a short distance away from the electrode. As a result of the conductivity of the ionized air and of the material, there is a negligible drop in potential at distances up to ½" away from the point of impressed voltage. This has a practical application in the use of the holiday detectors. For it means that good inspection does not require using D.C. voltage, nor of using an electrode that covers a large area. As the detector is moved along, each voltage peak from an A.C. wave, or from a pulse wave, inspects a fairly wide band around the pipe, and inspects it at a nearly even voltage.

In practice, it is necessary to have a design center for the voltage-generating equipment high enough that the test voltage will never fall below these minimum test voltages previously mentioned. There is nothing to be gained in increasing voltage beyond a point that insures maintenance of the minimum test value, and such practice will be harmful because it places an unnecessarily high stress on the dielectric material and could damage good coating.

In conducting the inspection, it is desirable to place a minimum stress on the coating material; so a study of the characteristics of dielectric breakdowns is important. Energy is required to cause a voltage breakdown of any material—air, mica, oil, or whatever dielectric material is placed under stress. Since energy is required, time, as well as voltage, is necessary for breakdown. The time interval needed for breakdown is a function of applied voltage and of the energy absorption. Data taken on breakdown through air shows that little energy is required. For example, if two large spheres are set with a spacing of 2.7 cm with an 8,000 microsecond pulse of voltage, 32 kilovolts cause breakdown. An 8,000 microsecond pulse represents ½ cycle of 60 cycle sine wave. With a 10 microsecond pulse, 35.4 kilovolts are necessary to cause breakdown. Thus, an increase in breakdown voltage is required as the time interval of voltage applications falls below 50 microseconds. For pulses of more than 50 microseconds duration the voltage necessary for breakdown is nearly constant. The phenomena for solid insulators is different in two respects. First, the energy required for breakdown is higher, and as a result a longer time interval is involved. Second, and more important, is the fact that damage due to high-voltage stress is accumulative. In a laboratory test, 4 layers of a standard impregnated paper insulation were subjected to various test voltages. With a 60 cycle sine wave and a time interval of 1 second, 4,900 volts were required to cause breakdown. With an impulse of 50 microseconds duration recurring at 1/30 second intervals, and applied for 1 second, 6,900 volts caused breakdown. It is apparent that the sparkover voltage required to break down air using a 50 microsecond pulse is not very different from that required using a 60 cycle sine wave voltage. There is a difference in the response of solid insulating materials, namely, the breakdown voltage gradient for solid materials is a function of time of voltage application.

To determine exactly how important these factors might be with respect to coating materials, an experiment was run on a coal tar enamel. The experiment gave accurate information on the dielectric strength of coal tar enamel under test. Sheets of 3" x 5" copper were dipped in coal tar enamel at a commercial pipe coating yard. Numerous samples were dipped, until a technique was worked out that gave a coating nearly free of air inclusions. The temperature of the enamel was adjusted until two dips would produce a coat of enamel which would hold up under 10,000 crest volts, but would break through under 20,000 crest volts. This was done because proper inspection of this type of coating should be made in the lower part of this range. A neon transformer was used as a source of high voltage 60 cycle sine wave voltage. A rheostat was placed in the primary circuit, so that continuously variable high voltage was available. A special pulse generator was constructed to generate 50 microsecond impulses at a rate of 30 per second. The pulse generator operated from a 6-volt storage battery. In order to make the output variable, a rheostat was inserted between the generator and the battery. A crest reading kilovoltmeter was used to measure the high voltage and was connected between ground and the exploring electrode. The exploring electrode was a ½" steel ball fastened to the end of an insulating rod. A spherical

electrode was used in order to have an evenly distributed electrical stress. In the tests the sample plates were held in a vise which was grounded to the voltage source used. One side of each plate was checked for voltage breakdown using the 60 cycle sine wave, and the other side of each plate was inspected for breakdown on the pulsating voltage. Inspection was made at five points on each side of the plates. A total of 10 plates were checked. The testing voltage was applied with a starting point of 5,000 crest volts and was increased at an approximate rate of 250 volts per second until breakdown occurred. After 5 breakdowns had been made on each side of a plate, the coating was removed from the surface, and a measurement was made of its thickness in the area adjacent to each breakthrough. Removal of the coating was accomplished by simply flexing the plate. Thus, sufficiently large areas could be taken from the surface to be checked with a micrometer. The breakdown potential and the coating thickness at each point were recorded. Thus, 50 measurements were made using 60 cycle A.C. voltage, and 50 were made using pulsating voltage. An algebraic division of the voltage required for breakdown by the thickness measurement gives the dielectric strength of the material. The dielectric strength varied from 500 volts per mil minimum to 890 volts maximum. The majority of values were close to the average for each of the two voltage types.

Under pulsating voltage, the average dielectric strength was 762 volts per mil, the minimum being 568 volts, and the maximum 890 volts. Under a sine wave voltage, the average dielectric strength was 692 volts per mil, the minimum being 500 volts per mil, and the maximum 860 volts per mil. From this data it can be seen that the coating will tolerate about 10 per cent more voltage of pulsating form than of 60 cycle sine wave form. This is, of course, of interest in the design of a holiday detector.

In field use, the coating is never subjected to more than a fraction of a volt of ground potentials; and where cathodic protection is provided, the voltage is only slightly higher. As previously mentioned, due to the thickness of the coating a high voltage is used of necessity. Since .020″ of good insulating material will effectively protect the pipe from ground currents, there is no object in breaking down such thin points if it can be avoided. Such thin spots can be due to air bubbles in the coating, or to high-temperature, low-viscosity application. The principal drawback of such thin points is a possible lack of mechanical strength.

As has been previously stated, the generator should deliver a voltage close to the minimum necessary for adequate inspection. It should do this for all possible conditions of coating, and for any size of pipe. The voltage, therefore, shoulld be held to within a narrow range, which is slightly above the minimum allowable. To design equipment capable of such good regulation requires a study of the nature of the load presented to the generator by the pipe. Impedance measurements made between an electrode and the pipe show a capacity load, shunted by a high resistance. The electrode acts as one plate of the condenser, the pipe as the other, and the coating as the dielectric in which energy can be stored. The resistance measurements made between a spring electrode and a 6″ coated pipe show a range of 150 to 500 megohms. Many pipe coatings have an outer wrap, which is a definite factor in the load. The wrapping material has a resistance per inch that is relatively small, depending upon moisture content. As a result the capacity between the pipe and the wrapper becomes an important part of the load, under certain conditions. A wrap of high moisture content is low in resistance and increases the capacity load by allowing the voltage to be spread over a larger area of the pipe. The complete load of the pipe may be represented as a group of condensers, each shunted by a high resistance and having a common ground. Each unit is connected in progression through a resistor.

With such a load, the effective value of the capacity becomes a function of frequency. This means that a capacity measurement made at 60 cycles will be several times higher than one made at 1,000 cycles, which will, in turn, be higher than one made at 20,000 cycles. Under any conditions of surface wrap conductivity, the high frequency measurement of capacitance, will always be lower in value than the low frequency measurements. This is because as the frequency of measurement is increased, the impedance of the various shunt capacities goes down. The series resistance remains constant. Thus, at higher frequencies, the effect of the resistance is measured. The series resistance of the wrap blocks the effect of capacity between pipe and paper wrap a short distance from the electrode. As a result of this, the capacity measurements between electrode and pipe at high frequency are more nearly constant for all moisture conditions of the paper wrap. To illustrate this, some measurements were taken and are given below: A 1,000 cycle measurement on 6″ pipe when dry was 160 mmf. The paper wrapper was then dampened by wiping a section of the pipe with a damp cloth, and then allowing it to stand for 10 minutes. At the end of this period the pipe wrap appeared to be dry. However, the capacity then measured 3,800 mmf. Immediately after this 1,000 cycle measurement, a measurement was made of the impedance using a 50 microsecond pulse. It indicated a capacity of 800 mmf. wet, as compared to 160 mmf. dry, and is sufficiently different from the 1,000 cycle measurement of 3,800 mmf. that even a 10 percent error of measurement would be of little consequence.

The load will range from 50 mmf. on small dry or unwrapped pipe coatings to 30,000 mmf. for damp coatings on large pipe. The above range applies to 60 cycle sine wave voltage. On a pulse type of voltage of 50 microsecond duration, the capacity range under these conditions is from 50 mmf. to 4,000 mmf. Thus the load range presented to a pulse generator is narrower than that presented to a 60 cycle sine wave generator.

In the case of a generator delivering 60 cycle sine waves to the testing electrode, the impedance range is from 50 megohms to 90,000 ohms. With a transformer designed to deliver 14,000 volts crest at no

load, and loading down to 10,000 crest volts at maximum load, the current drain may be as high as 80 milliamps. This gives a volt ampere output of 600. Unless an extremely large transformer is used, such as one with a 1,500 volt amp rating, a manually operated rheostat is essential to obtain a control on the output voltage. Use of such a rheostat has the disadvantage that it makes necessary occasional checking of the output so that shifts in load will not cause extreme variation in the testing voltage. Such a load shift might occur, for example, on leaving an area of pipe exposed to direct sunlight and entering into a shaded area.

A properly designed magnetic energy storing system will give an output voltage that has the same loading characteristics as the 60 cycle sine wave generator. Here again, the regulation of the output voltage can be arbitrarily decided upon; and, by providing a large enough transformer, the regulation can be made as good as desired. A transformer having 30% voltage regulation from no load to full load would be about 50% larger than one having 100% voltage regulation. A 30% variation means that the peak voltage delivered would never be over 13,000 volts on no load, and would never be under 10,000 peak volts for the heaviest loads. This system has the advantage of allowing inspection with a much lower drain on the power source, and as a result the equipment can be much lighter than when a continuously applied voltage is used. It has the further advantage that this impulse type of wave will do a minimum of damage to the coating, because the average time of voltage application is low. The spark transformer necessary to handle the same load as a 60 cycle sine wave transformer is comparable in size and weight.

A third system for generating voltage takes advantage of the capacitive type of load presented by the pipe in a manner which allows for minimum energy drain and minimum weight and size of components. If one connects, in series, a D.C. power source, a reactor, a condenser, and a switch, when the switch is thrown to closed position, a flow of current will start from the power source. The condenser is thus charged; and, in charging, the voltage across the condenser will reach a value essentially twice that of the power source, providing that the losses in the reactor and switch are relatively small. This phenomena will occur irrespective of the values of the condenser or of the reactor. Changing these values will change only the time interval required for the full charge to be placed on the condenser. With reference to holiday detectors, the electrode and the pipe represent a condenser of variable value. In a theoretically ideal system a transformer is required to change the voltage of the energy source to ½ that desired on the pipe coating. A switch is required in the primary circuit of the transformer to make and interrupt current flow. A reactor is needed, either in series with the primary of the transformer, in series with the output of the transformer, or one can use reactance between the primary and secondary of the transformer. When the switch is thrown, the closed position current flow will start, and it will increase to a crest value at the time the voltage has reached ½ desired value on the pipe coating. From that point it will decrease until it has reached a value of zero when the voltage on the pipe has reached its crest. This is the ideal performance, and would require a transformer of 100% efficiency, and zero magnetizing current. The peak value attained by the current will be a function of the capacity in the load circuit, and of the time interval needed to place the full voltage on the pipe coating. At the instant that the full voltage is realized, the switch in the primary of the transformer must be opened, and whatever small field in the transformer has been built up will then collapse, so that the circuit is ready for another impulse at a time later. The difficulty of the system would be to make a switch which would realize when the full voltage had been attained, and would then open the primary circuit. In that the time interval would vary as a function of the load capacity, the time interval cannot be set. The peak current varies as a function of this time interval, in inverse proportion to the interval. It has been pointed out that an extremely fast voltage peak is highly desirable from the standpoint of placing minimum strain on the coating material. It is further desirable from the standpoint that it places the minimum load on the voltage generator. Further, the smaller this time interval is made, the smaller the physical size of the spark transformer can be.

However, a fast time interval means the switch must have high current capacity; and, in the practical design of the equipment, it would have to carry as much as 1,000 amps at peak current flow from a 6-volt battery. The impedance of the battery and leads in this case would become extremely important, and the efficiency of the circuit would tend to be low. In order to combat this, the next step would be to convert the low potential of the battery to a higher voltage so that the peak current need not be so high. In practice this is what is actually done. A 6-volt storage battery is used as the primary source of power, and by use of a small vibrator the voltage is converted to approximately 300 V.D.C. At this potential the peak current required is about 20 amps. In order to have a low impedance source, a condenser is placed across the output from the intermediate voltage converter. The problem still remains as to a switch that knows when to open the power circuit. The system is compromised by using a charged condenser in lieu of a switch. The condenser is charged from the intermediate voltage source. This charged condenser is then discharged into the primary of the spark transformer. The reactance between windings in the spark transformer completes the voltage doubler circuit. When the charged condenser has discharged all of its energy into the spark transformer, current flow will reverse itself. Thus an oscillation will take place, until all of the energy originally contained by the condenser will be dissipated.

The investigation of coating characteristics discussed was utilized in equipment design only during the past few years, and it has resulted in the rapid

development of holiday detectors that have close to ideal inspecting characteristics. The most modern equipment will produce a voltage that stays within the range of from 10,000 to 14,000 crest volts for nearly all conditions of the coating, and for all conventional sizes of pipe now used. A detection circuit is utilized which gives clear signals to the operator whenever a holiday is encountered. It is not necessary to listen or watch for a spark as an indication of breakthrough. Because of stabilization of the output voltage, the control of the equipment is accomplished through use of just an off and on switch. Weight has been minimized, as an aid to handling efficiency, through use of lightest weight structural materials available, and by the development of smaller electrical components. Power consumption is held to a practical minimum so that a small lightweight battery is sufficient to drive the circuit. Full advantage is taken of the fact that high frequency pulse voltage occurring at low frequency intervals is least damaging to coating materials. The latest equipment gives pulses that are so extremely short that the time of impressed voltage on the coating is only .03% of the operating time. This means that the equipment would have to operate for 1 week to be equivalent to D.C. voltage applied for 1 minute. A further advantage, of course, is that a relatively low power demand is imposed upon the energy source.

The investigations that have led to the development of the holiday detector in its present form will be continued in the belief that further improvements may be made which will aid in protecting this country's ever-expanding network of underground steel pipe.

A Note on the Effect of Variations Of Exposed Area on the Solution Potential And Corrosion Rate of Low Carbon Steel*

By J. M. BIALOSKY

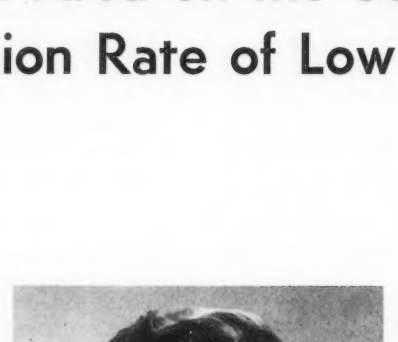
Abstract

Solution potential and weight losses were measured for replicate samples from one lot of low carbon steel. The tests were conducted in a circular path apparatus with aerated 3.5 percent salt solution as the corroding medium. The exposed area was varied by masking the edges and backs of the specimens.

The average solution potential was constant irrespective of exposed area. The average corrosion rate, standard deviation of corrosion rate, and standard deviation of potential measurements decreased with increasing area up to 25 square centimeters and then remained constant for larger sample areas.

Crevice corrosion at the wax-metal-liquid line is suggested as the cause for the variations of corrosion rate with area.

★A paper presented at the Fifth Annual Conference of The National Association of Corrosion Engineers at Cincinnati, Ohio, April 11-14, 1949.



J. M. BIALOSKY

Senior technologist at Carnegie-Illinois Steel Corp. Research Laboratory. His present work in the field of corrosion involves the study of potentials of metals and alloys in aqueous environments, cathodic protection and the corrosion of tin plate. Active in the Corrosion Division of The Electrochemical Society, he recently also was named treasurer of the Pittsburgh Section, National Association of Corrosion Engineers.

Introduction

THIS WORK WAS carried out in conjunction with a project for determining solution potentials of metals and alloys in various aqueous media. The establishment of such tables of data for the engineering alloys require that the estimates of the potential values be as accurate as possible. In order to obtain good reproducibility of replicate measurements and, by inference, good accuracy of the data, several exposure factors must be controlled. In this work the concentration of the corroding solution, temperature, aeration, solution volume, and velocity were controlled.

Experimental

The steel was obtained from one lot of cold reduced tin mill black plate which had been annealed and temper rolled. The analysis conformed to the specifications for low metalloid steel for tin plate, as given in Table I. The coil had been slit and a portion cut into approximately 6-inch squares which were

Table I

Analysis of Low Carbon Steel

	Percent
Carbon	.079
Manganese	.44
Phosphorus	.001
Sulfur	.035
Silicon	.006
Copper	.024
Nickel	.04
Chromium	.01

randomly selected and cut into 3 by 6-inch panels which were then shuffled and stored in a desiccator. These panels were then cut to a suitable size for the particular test and cathodically cleaned in hot 3 percent sodium carbonate solution. The test specimens were weighed, bolted to the supporting wire, and masked to define the desired area. The masks were cut from heavy graph paper having a millimeter ruling. These were moistened in 1 percent sodium carbonate solution and pressed with a blotter on to the steel surface. A molten rosin-beeswax mixture was brushed over the edges of the mask and on all the exposed metal surfaces. When the wax mixture had cooled sufficiently, the mask was stripped by lifting one corner and peeling off the paper.

The samples were placed in a circular path corrosion testing machine[1] and exposed for 24 hours. The corroding solution was 3.5 percent sodium chloride which was prepared from reagent grade salt and deionized water having a minimum specific resistance of 50,000 ohms per cubic centimeter. The solution was prepared and used in rectangular Nonex glass battery jars, and eight liters of fresh solution were used per jar in each test. Three jars were placed in a water bath and maintained at 30 C ± 1 C. The solution was continuously aerated by passing humidified air through a sintered pyrex gas diffuser in each jar. The diffusers were fitted with pyrex tube chimneys to prevent impingement of the bubbles on the test samples. The linear velocity of the samples was maintained at 38.5 feet per minute.

The solution potentials were recorded on a six-point Leeds and Northrup Micromax recorder and a saturated calomel half cell was used as the reference electrode.

The majority of the tests were made using two samples in each jar; three tests were made using one sample per jar. The actual areas used were varied between 2 sq. cm. and 49 sq. cm.

After the 24-hour exposure the pieces were removed from the machine, rinsed, scrubbed with white soap and a brush to remove the corrosion products, and dried. The stop-off (masking) mixture was removed in trichlor-ethylene vapor and the samples recleaned cathodically in sodium carbonate solution. Any remaining corrosion products were readily removed after the cathodic cleaning by wiping with a paper towel. A final rinsing, drying, and weighing completed the test.

Discussion

The potential data are shown graphically in Figure 1 for both the average values and standard deviations

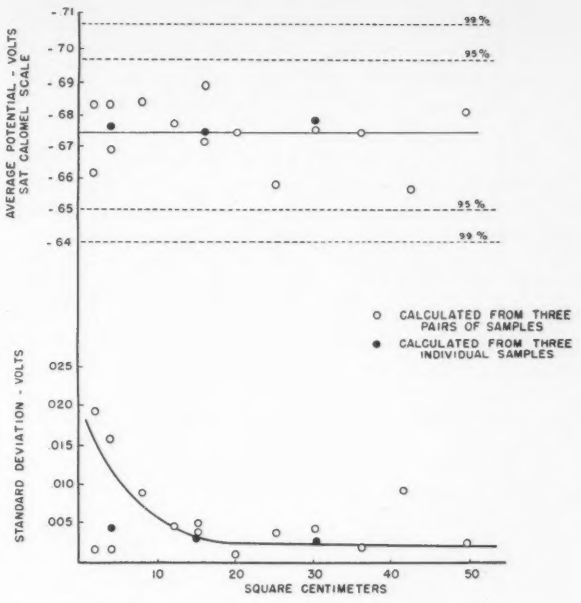


Figure 1—Average potential and standard deviation vs. exposed area.

for three or six samples of a given area. The open circle values were calculated from three pairs of samples and the solid circle values were calculated from three individual samples as described below. A typical calculation is shown in Table II.

The average solution potential data fall in a hori-

TABLE II

Typical Data and Calculations of Average ($\bar{x}$) and Standard Deviation (s)

Sample Number	Initial Weight	Final Weight	Weight Loss (mg)	24-Hour Potential
1	10.0709	9.9889	82.0	—.671
2	10.1710	10.0961	74.9	—.676
3	10.2546	10.1799	74.7	—.675
4	9.8540	9.7789	75.1	—.675
5	9.9960	9.9216	74.4	—.675
6	10.1133	10.0318	81.5	—.674

Area = 36 sq. cm. = .36 sq. dm

The following symbols are used in the calculations shown below:

N = number of samples
x = an individual value
$\bar{x}$ = the arithmetic average or mean
Sx = the sum of the values of x
Sx^2 = the sum of the values of x^2
$S(x-\bar{x})^2$ = the sum of the squares of the deviations from the average
s = the standard deviation
s^2 = the square of the standard deviation or the variance

	Corrosion Rate	Potential
N	6	6
Sx	462.6	—4.046
$\bar{x} = \frac{Sx}{N}$	77.10	— .6743
$S(x^2)$	35,731.72	2.728368
$(Sx)^2$	213,998.76	16.370116
$(Sx)^2/N$	35,666.46	2.728353
$S(x-\bar{x})^2 = (Sx^2) - \frac{(Sx)^2}{N}$	65.26	.000015
$s^2 = \frac{S(x-\bar{x})^2}{N-1}$	13.052	.000003
s	3.613	.00173

The average corrosion rate per .36 sq. dm was 77.10 mg which is equal to 214.12 mdd. and the standard deviation is equal to 10.03 mdd.

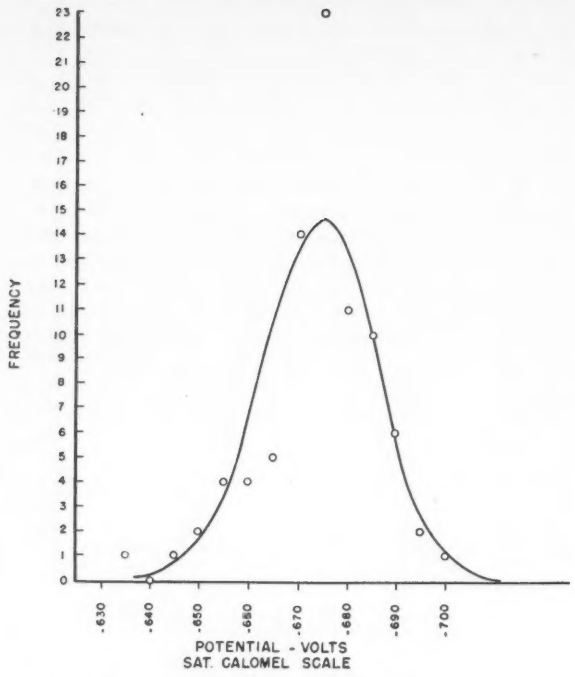


Figure 2—Theoretical and actual frequency distribution of potential data obtained from tests with two samples per jar.

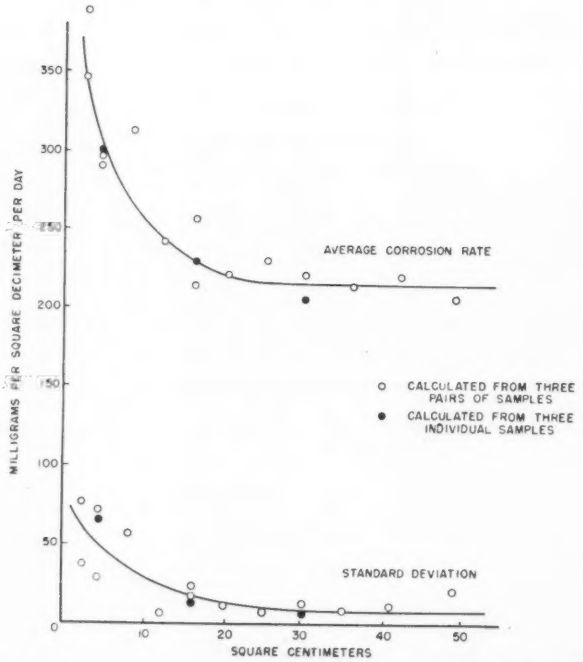

MILLIGRAMS PER SQUARE DECIMETER PER DAY
SQUARE CENTIMETERS
AVERAGE CORROSION RATE
CALCULATED FROM THREE PAIRS OF SAMPLES
CALCULATED FROM THREE INDIVIDUAL SAMPLES
STANDARD DEVIATION

Figure 3—Average corrosion rate and standard deviation vs. exposed area.

zontal band and are all within the normal control limits. There is no evidence of any change in the potential with variations of exposed area. Because steel in aerated salt solution is under cathodic control, the potentials which are being measured are essentially those of the local anodes.[2] For replicate samples of the same lot of steel under the given conditions of exposure, the local anode potentials are similar and the variations of exposed area do not influence the values.

The standard deviations do indicate a general decrease with increasing area, although in two tests, one of 2 sq. cm. and one of 4 sq. cm., the standard deviations were low, indicating excellent agreement among the six values. In view of the higher values for the standard deviation found in duplicate tests with the same exposed areas and the data for 8 sq. cm., these two low values are considered fortuitous and are not normally to be expected.

In view of the distribution of the average potential values in the control chart (Figure 1), a distribution curve was constructed which included the 84 measurements which were obtained when pairs of samples were exposed in each jar. The actual distribution and the calculated theoretical normal curve are shown in Figure 2. The deviations from the calculated curve are normal as measured by χ^2 test, although more points fell near the mean than indicated by the theoretical curve.

The weight loss data are shown in Figure 3 and indicate a rapid decrease in average corrosion rates with increasing sample size, which levels off above 25 sq. cm. The standard deviations of the weight loss data are similar to the standard deviations of the potential data and the above remarks apply to these values.

The decrease in corrosion rate with increasing area was not anticipated when the tests were planned. The possibility of the build-up of iron in the solution retarding the corrosion was considered improbable because the films of solution were rapidly saturated with iron at the metal surface, as evidenced by the corrosion product which adhered to the sample and was visible on all samples within 10 minutes after immersion. Three runs were made, however, in which only one sample was exposed in each jar. These data were not significantly different from those wherein pairs were exposed, although the area-to-volume ratio was half of the ratio when pairs were exposed. It is apparent that in this case, where a porous insoluble corrosion product is formed, the amount of corrosion product in the body of the solution does not influence the corrosion rate.

An inspection of the exposed test pieces gave a clue to the cause of the reduction of corrosion rate with increasing area. It was noted that the attack occurred more generally at the line of the wax mask as shown in Figure 4. The wax-metal-liquid junction may have resulted in crevice attack[3] which intensified the corrosion at these lines. With small exposed areas, the ratio of edge to area is greater than with larger areas and this may be the explanation for the influence of area on the corrosion rates found. As a result of the accelerated attack at the wax-metal-liquid line, the accuracy of the measured corrosion rates is subject to question. This discrepancy does not, however, affect the accuracy of the measured potential.

Conclusions

The following conclusions have been drawn from these tests using one lot of steel exposed in a cir-

cular path apparatus with aerated 3.5 percent sodium chloride:

(1) The mean solution potential for three or six replicate samples is constant and not influenced by the exposed area.
(2) The standard deviation of the above potential measurements decreases with increasing area up to approximately 25 sq. cm. and is constant for the larger areas investigated (up to 49 sq. cm.)
(3) The potential data are normally distributed about the mean value.
(4) The measured corrosion rates decrease with increasing area of steel surface exposed up to approximately 25 sq. cm.
(5) The variations in the measured corrosion rates may be associated with crevice attack at the wax-metal-liquid interface.
(6) The standard deviation of the weight loss data decreased with increasing exposed area up to 25 sq. cm. and remained constant in the range investigated (to 49 sq. cm.).

References

1. O. B. J. Fraser, D. E. Ackerman and J. W. Sands, *Ind. Eng. Chem.*, **19**, 332-338 (1927).
2. R. B. Mears and J. M. Bialosky, Cathodic Protection—A Symposium, ECS and NACE. National Association of Corrosion Engineers, Houston, Texas, 1949. Page 37.
3. U. R. Evans, Metallic Corrosion, Passivity and Protection. Longmans, Green and Co., New York, 1948. Page 496.

DISCUSSION

Question by J. Preston Engle, Babcock-Wilcox Research Div., Alliance, Ohio:

"Will you explain more fully the method used for masking the edges and backs of test panels?"

Author's Reply:

The stop off wax mixture was made by melting together approximately equal weights of white rosin and beeswax. The mixture should not be excessively heated. We have found that a controlled hot plate is suitable for melting and maintaining the mixture at the proper temperature. The texture of the wax may be varied by changing the proportions of the materials. If the coating is too tacky, rosin may be added, whereas a brittle coating will require additional beeswax. The mixture is brushed onto the test panels with a camel's hair brush, using overlapping strokes to insure complete coverage.

Stripping the paper mask from the sample is readily accomplished by using a pin to lift one corner and peeling off the paper. The wax should be partly cooled on the test piece before removing the paper mask to prevent running of the coating The technique can be determined readily with a little practice.

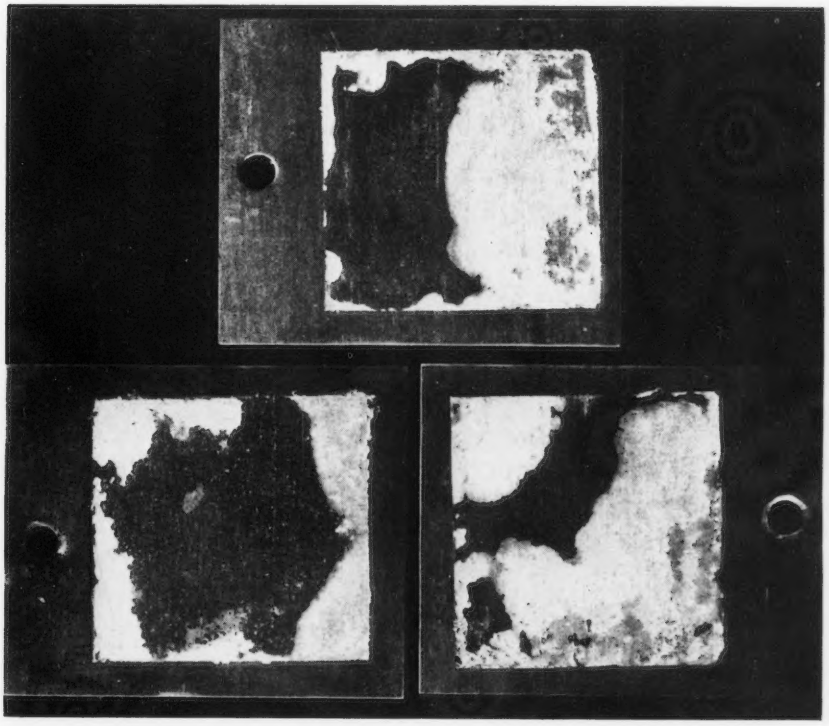


Figure 4—Corrosion test samples after exposure and cleaning. The light areas are etched, showing the generally normal attack in the central areas but almost 100 percent attack at the edges of the mask. (Magnification 1X)

Discussions

Discussion on "CORROSION OF TELEPHONE OUTSIDE PLANT MATERIAL," by K. G. Compton and A. Mendizza, CORROSION, **5,** No. 6 194-97 (1949) June.

By C. J. Couy, Duquesne Light Company, 435 Sixth Ave., Pittsburgh, Pa.:

In this paper a very good presentation is made of the problems facing the design and operating engineers of outside plant in public utilities; and of the materials used and considered for use in meeting these problems economically. Replacements, especially if premature, of units of material in such extensive use can become quite costly. Mitigation of deterioration at reasonable cost is, therefore, very much worthwhile.

In their presentation on the durability of the lighter zinc-coated pole-line items shown in Figure 2 of the paper, the authors refer to "cable rings which had weathered in a *relatively short time* in a *highly industrialized* area." Such reference is too general to convey definite information and it would be of interest if they would be more specific as to both length and kind of exposure.

In Figure 6 of this writer's paper, see references 4 and 5 of paper under discussion, are shown two telephone cable rings after 17 years exposure in ordinary industrial atmosphere. In the same figure as shown heavier, power-cable rings (6-I), which were removed after only 6 years from a position directly over the main tracks of a trunk-line railroad. It would be informative if the authors could compare their "highly industrialized area" to that in this writer's two cases.

In referring to Figure 3 of their paper, the authors state: "the effect of this *extremely severe attack"* having caused 2.0 oz. zinc-coated lashing wire to fail in a little more than two years. Again "extremely severe attack" is indefinite; and while the pH^2 mentioned for samples of dew collected from the cables is quite definite, its causes and the frequency of its occurrence is not specified. This would be of great interest. This writer has in his possession samples of lashing wire similar to that of Figure 3 of the paper which was removed after 16 months from the vicinity (less than 100 feet) of the exhaust stacks of the sulphuric acid pickling tanks of a galvanizing plant. Is this the type of environment the authors refer to?

"A comparatively short time" is again referred to in connection with Figures 4 and 5 in the paper referring to corrosion of pole-line hardware in marine atmosphere. It would be of interest to know the length of this exposure.

I believe the authors are too severe, as regards the use of lead for coating pole-line hardware, since there are many items, such as bolts, pins, racks, braces, etc., where the softness of the coating is no particular disadvantage.

It would also be of interest to have the authors' comment on aluminum coatings for pole-line hardware.

Of great value would also be any information available on the durability of zinc-coated anchor rods in general use on the telephone company's system.

Authors' Reply:

Mr. Couy's remarks relative to the indefinite nature of the time element in our paper suggests that he misunderstood its scope. As pointed out in the preamble, the intent of the article was to present, in a general fashion, a picture of the problems besetting the telephone engineer. As such, it was of necessity written in somewhat broad terms and no attempt has been made to make specific comparisons. The examples cited were used merely to illustrate some of the exposure conditions encountered.

It has been our experience, and we believe that of others as well, that it is extremely difficult to define precisely the corrosive nature of a given location. What will react as an ordinary industrial atmosphere at one spot, may behave in an entirely different manner a few feet away.

Mr. Couy apparently likewise misunderstood our position with regard to the use by the telephone companies of lead as a coating for pole-line hardware. With regard to the durability of galvanized anchor rods we refer Mr. Couy to the second column, second paragraph of page 197 of the June issue of CORROSION.

We have no experience with aluminum as a coating for pole-line hardware.

Discussion on "THE PULSE POLARIZER IN CORROSION TECHNOLOGY," by Dr. Hugh J. McDonald and Glenn A. Marsh, CORROSION, **5,** No. 8, 254-260 (1949) Aug.

By F. L. LaQue, The International Nickel Co., Inc., New York:

1. As the paper was presented it was noted that in comparing results with the pulse polarizer with results from other testing methods re the effect of changing some variable, a satisfactory degree of correlation was indicated. However, it appears that the pulse polarizer gave only relative values of corrosion rates and the question is raised as to how the pulse polarizer can provide information with respect to absolute rates of attack.

2. In view of the very short time during which the

pulse polarizer makes measurements, it would appear that advocates of its use must feel that polarization and de-polarization are not functions of time. Experience with polarization of metals in such a complex solution as natural sea water where the anode, and especially the cathode reactions are very complicated, has shown that the influence of time cannot be neglected in studies of polarization characteristics. It would be expected, therefore, that practically instantaneous measurements might be misleading in many cases.

3. The device as described does not appear to be well adapted to control of such factors as aeration, and especially velocity, which have a very great effect on polarization. Neglect of control of such factors in the use of the pulse polarizer might be expected to lead to results as unreliable as their neglect does with other corrosion testing methods and devices.

4. A question is raised as to the significance of the behavior of metal environment combinations under the very abnormal conditions resulting from the discharge of the relatively heavy polarizing current. It appears to be not unlike giving a man a very high fever and using his recovery from it as a measure of his normal health.

Authors' Reply:

Mr. LaQue's comments we believe are at least partly justified. We have presented here a technique for making a certain kind of polarization measurement, and have possibly laid undue stress on the empirical relationship of the curves to corrosion rate.

Questions by J. M. Bialosky, Carnegie-Illinois Steel Corp., Research Laboratory, Pittsburgh, Pa.:

1. Has the pulse polarizer been applied successfully to cases where the controlling reaction is not the cathodic liberation of hydrogen?

2. Can the pulse polarizer be used to determine the relative corrosivity of a group of similar electrolytes? For example, we know that in the case of tin plate food containers the corrosion resistance is influenced by the steel and by the weight of the tin coating. We do not have any suitable measurement of the corrosivity of the specific batch of food product which also influences the service life. Could the pulse polarizer be applied to this type of measurement?

Authors' Reply:

Mr. Bialosky's first question is partly answered by Figure 6 of the article as published in August, 1949, "Corrosion" magazine. In this figure a quanitative study is made of the influence of an anodic inhibitor in an oxidizing (hot nitrate) medium. On his second question, one can only speculate, since the instrument has not been applied systematically to electrolytes of the type in question.

Discussion on "ENGINEERING ASPECTS OF CATHODIC PROTECTION AS APPLIED TO PIPELINES," by E. P. Doremus, G. L. Doremus, and M. E. Parker, Jr., CORROSION, **5**, No. 9, 273-281 (1949) Sept.

By W. P. Noser, Humble Pipe Line Co., Houston, Texas:

Mr. Doremus presents curves which are relatively smooth. He has failed to show the problems encountered in the field with discontinuities showing up in the curves caused by shorted road casings, stretches of coatings of different kinds other than the one in the test site and the effects produced by large bare structures, such as tank farm terminals.

Authors' Reply:

Mr. Noser certainly is correct in stating that our calculated attenuation curves do not show up irregularities which would be caused by shorted road casings. However, the quite localized dips existing in two curves showing potential produced from an actual installation serve to show the depressing effect of shorted road casings. Two such points are those at 43,000 feet on the abscissa in the upper half of Figure 7 and at 149,000 feet on the abscissa in Figure 8. When conducting tests for current requirements it obviously is necessary to select a section of the line in which no such shorted road casings occur and to locate and take into account the current demand of any shorted casings elsewhere on the line in the computation of total current requirements for cathodic protection.

It is certainly necessary to take into account any variation in the type or method of application of the coating on a given line where tests are to be made for current requirements. As pointed out in our paper, it is necessary to repeat the current requirement tests so that at least one set of readings is available from a representative section of each of the different types of coatings.

The only effect of a large bare structure such as a tank farm terminal electrically tied into a line on which a test for current requirements is being made is to increase the magnitude of readings for current flow at the check points. The difference, which is the quantity being sought, will remain the same. Perhaps somewhat better precision in ascertaining this differential may be had if the magnitude of the readings are lower, and, therefore, in general it may be advisable to electrically isolate the pipe line under test from adjacent large bare structures.

Discussion on "AN INVESTIGATION OF STRUCTURAL STEEL SHOP COAT PRIMING PAINT," by S. C. Frye, Bethlehem Steel Company, Bethlehem, Pa., CORROSION, **5**, No. 9, 288-291 (1949) Sept.

Question by Dr. H. F. Haase, Marquette University, Milwaukee, Wis.:

Has any paint been developed which can be used for painting over a slightly oily surface, and which will have good adhesion? Research on the development of such a paint would be highly desirable.

Author's Reply:

I am not aware of any structural steel primer that

will have good adhesion and performance on oily surfaces.

Questions by I. E. Boberg, Chief Engineer, Chicago Bridge and Iron Co., Chicago, Ill.:

1. Did you paint immediately after applying linsed oil as a wetting agent?
2. Did it affect the drying time of the primer?

Author's Reply:

1. Yes.
2. It did increase drying time slightly, but not to an appreciable degree.

Questions by E. W. Wallace, Shell Oil Co., Inc., Houston, Texas:

1. Was the steel used in this test pickled before painting, and if so, was phosphoric acid used in the pickling bath?
2. Were any of the samples reported in this paper given a phosphoric acid treatment before painting?

Author's Reply:

One group of steel angles used with each paint tested was pickled with inhibited sulfuric acid. The pickled angles were used as a control inasmuch as the variables due to surface variations and contamination were removed. None of the angles used in the investigation were phosphate treated.

Remarks by Sol. M. Gleser, Upper Mississippi Valley Div., Corps of Enginers, St. Louis, Mo.:

The Corps of Engineers, Upper Mississippi Valley Division, has had excellent success with a phosphoric acid treatment consisting of 7 percent phosphoric acid, ¾ percent chromium sulphate and a wetting agent. The treatment is used only on sandblasted surfaces, and has considerably improved the life of paint coatings involving zinc chromate-pigmented primers. Care must be taken in using the treatment to insure that the reaction goes to completion, characterized by formation of a whitish gray powder on the surface. If unreacted products remain on the surface, characterized by a sticky-green residue, they must be washed off, and the treating solution further diluted for treatment of remaining surfaces. The treated surfaces need not be further washed or brushed after completion of the reaction but should be painted as soon after they are dry as practical. The solution may be applied by either brush or spray, but ledges where the solution can collect should be carefully wiped clean.

Author's Comments:

Mr. Gleser's phosphate treatment is specific for sandblasted surfaces. All of the tests in the subject investigation, except for the pickled control panels, were on mill-scaled or partially rusted steel surfaces. It is fundamental in this research program that sand blasting is impractical and unacceptable for the great bulk of fabricated steel structures.

Discussion on "WHY METALS CORRODE," by Dr. H. H. Uhlig, Massachusetts Institute of Technology, CORROSION, **5**, No. 6, 169-174 (1949) June.

Discussion by Norman Hackerman, University of Texas, Austin:

1. It is important to realize that the action of anaerobic sulfate reducing bacteria with respect to corrosion phenomena is primarily one of depolarization. It seems that many people who have not been working directly on this subject or who have not had reason to follow the literature on such work have the erroneous impression that the effect is due to the produced H_2S.

2. One of the aspects of reactions between metals and liquid media which has not been very thoroughly considered or investigated is the formation of complex ions. The effect of complexing agents on equilibria and rates is very important. Complexing agents may be such common materials as chloride ion or water. Very little consideration of the possible complexes in solution has appeared thus far in the literature.

3. One possible distinction between chemical and electrochemical corrosion is to consider the former as a direct electron transfer from reductant to oxidant and the latter as an electron transfer in which the oxidant and reductant are separated in space, perhaps by only one atom. In other words, the electrochemical change involves an electron transfer through a third body.

By Lyle R. Sheppard, Shell Pipe Line Corp., Houston, Texas:

Dr. Uhlig has presented an exceptionally well-prepared paper on the accepted reasons why metals corrode. He shows how only the cation concentration and type has any appreciable effect on the metallic corrosion in electrolytes. It is generally accepted that the anion concentration and type has no effect on this type of corrosion.

If this were true there would be no electrical potential between two electrodes in a cell composed of two solutions having the same concentration and type of cations, but with different type anions: for example, sodium hydroxide and sodium acetate. I have not found this to be true.

Using salts of the same metal in equivalent concentrations of cations but with different types of anions I have observed as great a potential difference as 80 mv between the electrodes in the two solutions. Factors such as electrode differences, and contamination of containers have been considered and compensated for in these tests. The only variable was the type of anion.

In practically all tests the anode was in the solution with the anion having the greatest mobility. To me this means that the anion concentration and type can have an appreciable effect on metallic corrosion in electrolytes.

In any case, I believe that further investigation along this line is justified.

Author's Reply:

There is no doubt that anion type and anion concentration are important factors in determining the corrosion rate. This is true because the anion often determines the relative conductivity of the electrolyte, the nature of the corrosion product films that may form, or the nature of complexes, organic or inorganic, that bear relation to the relative corrosion tendency of the metal. Where corrosion is by

hydrogen evolution, the anions and the cations may determine the pH and total acidity of the solution, thereby significantly affecting the rate of attack.

Usually, the cation is less important than the anion in corrosion reactions involving alkali metal salts, but this situation may change as one goes to the heavier metal salts.

By William F. Gross, Tretolite Company, Webster Groves, Mo.:

My question concerns the fundamental cause for the property of passivation (where the term is not used broadly to include inhibition and protection). Apparently two theories explaining passivation have been proposed: The passivating element or compound is adsorbed on the metal surface to form a physically protective coating; the passivative element or compound is of the electron-attracting type, so that the incomplete inner electron shell is maintained in the (transition) metal, which condition is of the lowest energy level and, consequently, the condition of passivity.

I was wondering if new evidence had been found substantiating either theory.

Author's Reply:

Actually, the theory that passivity is accompanied by adsorbed films or by a certain electron configuration of the base metal belongs to one and the same theory. The second theory referred to in this question is probably the oxide film theory which ascribes passivity to physical protection of the base metal by a layer of oxide or other compound acting as a diffusion barrier. There are many instances in which there appears to be no doubt that this latter theory applies; namely, passivity of aluminum and magnesium in water, or lead in sulfuric acid.

With the stainless steels or with iron passivated by chromates, for example, both the electron configuration theory and the oxide film theory have been proposed as explanations. The oxide film theory ascribes passivity to the formation of a chromium-iron oxide on the surface by reaction with the environment, which is essentially impermeable to oxygen or other constituents of the environment. On the other hand, the electron configuration theory assumes that oxygen, for example, adsorbs on stainless steel, and that chromate ion adsorbs on iron, in such a way as to satisfy secondary valence forces of the metal surface, accounting for subsequent lower affinity of the metal for its surroundings, and which we call the passive state. Adsorption of this kind is possible on the stainless steel surface because the electron configuration of the alloy is favorable. On a metal such as copper, adsorption of this kind is not possible; rather, the oxygen reacts immediately to form an oxide which, however, is only slightly protective. Hence, copper is not made passive in the same sense when exposed to aerated aqueous solutions.

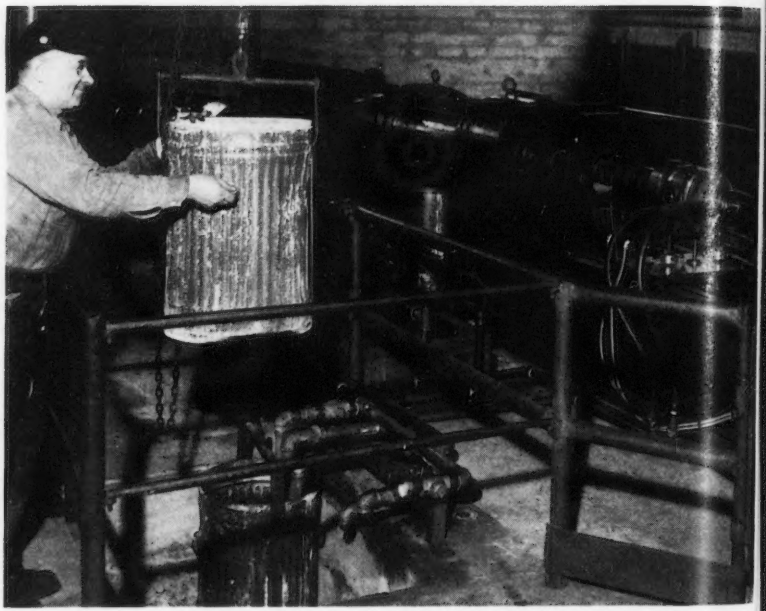
In time, the adsorbed layer on stainless steels or iron gives way, in part, to an oxide which forms slowly and which may effect a physical barrier on the metal surface. The metal may, therefore, receive increased protection from this secondary film. It is thought, however, that the primary cause or source of passivity is the adsorbed film, whatever its composition. Experiments are now under way in more than one laboratory for the purpose of further exploring this mechanism of passivity.

DISCUSSIONS ARE INVITED

Readers who wish to submit written information additive to articles published in CORROSION, or who wish to register differences of opinion with respect to any articles are urged to send such discussions to Dr. F. N. Alquist, Chairman, NACE Editorial Review Committee, Organic Research Laboratories, 20A Building, Dow Chemical Co., Midland, Mich. Doctor Alquist will submit such discussions to a member of the review committee, and after review and approval the discussion will be published.

The expression of opinions about or the addition of information to that contained in technical articles will advance the interests of NACE and make CORROSION more valuable to the membership.

High Speed Stress and Corrosion Tester Developed for Oil Well Drill Pipe



Photograph shows workman about to substitute a tank of fresh brine for spent solution used to test the stress-fatigue and corrosion resistance of seamless oil well drill pipe. The rotating specimen is seen in the unit at right.

FULL-SIZED specimens of oil well drill pipe are tested for resistance to stress failure and corrosion from brines in a machine developed by United States Steel Corp. National Tube Co., works at McKeesport, Pa. The six-ton unit tests sections of seamless pipe up to 8⅝-inches in diameter and from 24 to 120 inches long at rotational speeds up to 1000 revolutions per minute and at bending forces up to 1,200,000 inch-pounds.

A 25-horsepower variable-speed motor drives the main spindle to which the sample to be tested is attached by a tool joint. The free end rotates in a roller bearing in the loading housing. Pivots connect this housing to a yoke that takes the pull of a spring that can exert a force of 10,000 pounds. The free end of the pipe is bent downward a measured amount, and as the pipe rotates the walls are alternately stretched and compressed.

Although test stresses are relatively low the cumulative effect of multiple reversals ultimately will cause the pipe to fail. A microlimit switch can be set to shut off the machine when failure occurs. Adjusting nuts on the loading yoke limit the drop of the loading end in case of specimen failure.

Brine is circulated through the interior of the pipe during the test, simulating the actual conditions under which the pipe will be used in drilling operations. Corrosive brines are known to accelerate failure of stressed metals operating under these conditions. Manifold piping permits switching flow of brine from one tank to another to change fresh for used solution. Composition of the solution is checked frequently to maintain uniform test conditions.

Drill pipe rotational speeds in actual drilling are near 100 revolutions per minute. The higher speed at which the test machine flexes the pipe specimen are believed to provide a dependable accelerated test method.

NACE News

North East Region Vote Favors Board Additions

Members of NACE's North East Region voted 267 to 3 in favor of adding an officer from each section as a member of the region's board of trustees, by giving approval to an amendment to Article V, Sec. 1 of articles of organization. The vote was by letter ballot conducted by L. B. Donovan, regional secretary-treasurer.

Under national NACE regulations the change in the articles for the region must be approved by the association's board of directors before becoming effective.

Cleveland Section Sets Seven Month Program

Cleveland Section has outlined a seven-month program of activities beginning with its September meeting when M. W. Daugherty, head of Aluminum Company of America's Cleveland section research laboratories will speak on "Service Tests Solve Aluminum Cylinder Head Corrosion Problems." The section meets third Tuesdays.

Other scheduled meetings, and featured speakers include:

October—R. B. Mears, Carnegie-Illinois Steel Corp. Topic, "Passivity and Inhibition." This meeting is to be held in conjunction with the Metal Show at Public Auditorium.

November—Meeting on cathodic protection, speaker to be named later.

December—No meeting.

January, 1950—Joint meeting with The Electrochemical Society.

February, 1950—C. P. Larrabee, Carnegie-Illinois Steel Corp., "The Effect of Composition of Steels on Corrosion."

March, 1950—M. G. Fontana, chairman department of metallurgy, Ohio State University. Joint meeting with American Institute of Chemical Engineers.

April-May—Open.

New officers of the section are E. W. Veereke, Heil Process Equipment Corp., chairman; Raymond B. Hoxeng, Case Institute of Technology, vice-chairman; J. A. Thornton, Cleveland Tool & Supply Co., secretary-treasurer. Advisory council members are L. W. Davis, Aluminum Co. of America; Hugh Brown, W. S. Tyler Co.; Paul Gegner, Pittsburgh Plate Glass Co.; C. Langdon Campbell, Diamond Alkali Co.

Notices of future meetings of NACE subdivisions are carried monthly under the heading "NACE Calendar" in each issue of CORROSION magazine. Notices for this column should be sent to Central Office.

113 Students From 19 States Register For NACE Short Course in Corrosion

NACE CALENDAR

NORTH EAST REGION—Board of trustees meeting scheduled November 18.

METROPOLITAN NEW YORK SECTION—Meetings are scheduled Nov. 9, 1949; Feb. 8 and May 10, 1950.

SHREVEPORT SECTION—Regular meeting day is second Thursday monthly.

TULSA SECTION—Meets second Monday monthly.

SAN FRANCISCO BAY AREA SECTION—Next meeting will be held in October, first Tuesday, unless changed later.

GREATER ST. LOUIS—Meets October 17, Gun Room, Edmonds Restaurant, St. Louis.

CLEVELAND SECTION—Meeting scheduled in conjunction with the 31st National Metal Show, October 17-21.

Greater St. Louis Section Will Hear Frank LaQue

First scheduled 1949 fall meeting of the Greater St. Louis Section NACE will be held Monday, October 17 beginning at 6:15 p.m. in the Gun Room of Edmonds Restaurant. Frank LaQue, International Nickel Co., Inc., N. Y., will speak on "NACE—Its Aims and Role in the Development of Experience in Combatting Corrosion Problems."

A preliminary business and social meeting was held September 19 in order to bring members up to date on work of the executive committee during the summer.

New officers are Phil H. Smith, Nooter Boiler Works, St. Louis, chairman; Frank L. Whitney, Monsanto Chemical Co., vice-chairman; E. L. Rice, Titanium Div., National Lead Co., secretary-treasurer; Wm. F. Gross, Tretolite Co., corresponding secretary. The executive committee, in addition to the officers and the past chairman, Otto Fenner, Monsanto Chemical Co., includes H. O. Nordquist, William Keller, William Deacon and Ed Ellwood.

Students from 19 states registered for the Short Course in Corrosion at Universit yof Texas, Austin, September 12. First day registration was 113.

Course topics followed the schedule previously announced, but there were some changes in instructors. The Wednesday protective coatings lecture was by W. F. Fair, and theoretical aspects of cathodic protection Thursday was given by Lyle Sheppard while chemical treatment, the lecturer for which was not announced previously, was H. E. Waldrip.

The official schedule gave the following information about motion pictures, which were shown afternoons: (Titles are approximations of subject matter and not exact) Monday, Electrochemistry and Watts in Glass; Tuesday, Nickel Mining, Corrosion, Birth of an Oil Field; Wednesday, Welded Pipelines, Coating Pipelines; Thursday, Construction of Pipelines, Reconditioning Operations on Pipelines.

Following is registration by states; Arkansas 2; Arizona 1; California 2; Illinois 2; Indiana 2; Iowa 1; Kansas 2; Louisiana 13; Michigan 1; Mississippi 2; Nebraska 2; New Jersey 1; New Mexico 1; New York 3; Ohio 3; Oklahoma 9; Pennsylvania 1; Rhode Island 1; Texas 64.

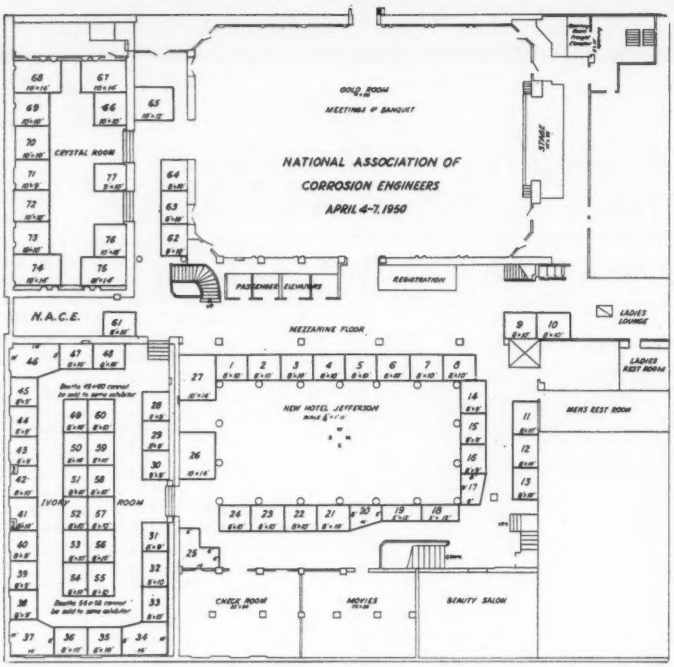
Shreveport Section's second annual barbecue was held September 8 at the 40 and 8 Club on Cross Lake with about 70 members and guests present. The gathering initiated the fall and winter program of the section. The October meeting, scheduled to be held at the Caddo Hotel, Shreveport on the thirteenth will feature the showing of a Perrault Brothers film on the construction of the Trans-Arabian Pipeline.

Houston Section's scheduled September 22 meeting at assembly room, Central YMCA, Houston included an address by F. L. LaQue of the corrosion research laboratory of The International Nickel Co., N. Y., on "General Aspects of Industrial Corrosion Problems in the Gulf Coast Area."

North East Region's Board of Trustees for a meeting September 20, at 10:45 a.m., Room 500, Atlantic Refining Co. Building, 260 South Broad St., Philadelphia, scheduled the following agenda:

1. Plans for region-section meeting at Pittsburgh in mid-October.
2. Plans for region-section meeting at Baltimore in November.
3. Selection ofn ominating committee for region officers to serve during 1950.
4. Proposals for stimulating activity in New England.
5. Discussion of subjects to be presented at the regional management committee meeting October 2 at Dallas, Texas.

Details Given About Exhibit Space at St. Louis



Arrangement of exhibit booths at Hotel Jefferson, St. Louis, Mo., for the 1950 NACE conference, April 4-7.

Brochures, Contracts Are Available Now

Details about exhibits, exhibit space and arrangements were revealed this week by O. E. Murrey, chairman of the 1950 NACE Exhibits Committee who is in charge of that portion of the association's activities during the conference scheduled April 4-7 at St. Louis, Mo. Exhibit contracts and brochures are available now on request from A. B. Campbell, executive secretary of NACE at Central Office.

The 1950 exhibit will comprise 77 booths in the Hotel Jefferson, conference headquarters, and all will be readily accessible on the mezzanine floor adjacent to one of the large meeting rooms. In order to make more time available for visiting exhibits by those attending the conference the length of the lunch hour has been increased. Scheduled lunch hour is noon to 2:30 p.m. Standard booth equipment will be furnished by the Grosch-Tucker Decorating Co., 108 North 6th St., St. Louis 1, Mo.

Exhibit space will be allocated according to the originating post mark date. Because of the possibility wanted space already may be sold, those applying for space are asked to make three selections, so alternate assignments may be made if necessary. Because all booth space was sold early last year and some companies requesting space could not be accommodated, it has been suggested that contracts be submitted promptly. Further details on exhibit questions can be secured from the executive secretary, A. B. Campbell.

K. D. Wahlquist, Dallas, has been named chairman of the North Texas Section, according to information from C. I. Sims, retiring secretary. The election took place May 27. Other officers are John R. Ligon, Sinclair Refining Co., Fort Worth, vice-chairman; John L. Pool, Magnolia Pipe Iine Co., Dallas, secretary-treasurer, and N. H. Simpson, Consolidated Vultee Aircraft Corp., Fort Worth, assistant secretary-treasurer.

Western Region heard Prof. Pierre Van Rysselberghe, Department of Chemistry, University of Oregon, speak on "Polarographic Studies of Corrosion," at Roger Young Auditorium, Los Angeles, at a dinner meeting September 7.

Changes in officers, or changes in addresses of officers should be brought to the attention of Central Office by secretaries of NACE regions and sections. Changes will be made as soon as possible in the monthly list "Directory of Regional and Sectional Officers."

TECHNICAL PAPERS
Scheduled for
November Publication

EXPERIENCE AND ECONOMIC BENEFITS FROM CATHODIC PROTECTION OF GAS DISTRIBUTION SYSTEMS, *by A. W. Peabody and C. W. Woody.*
ELECTROLYTIC CORROSION OF STEEL IN CONCRETE, *By G. M. Magee.*
CORROSION TESTS IN THE PROCESSING OF SOAP AND FATTY ACIDS, *by W. Z. Friend and J. F. Mason, Jr.*

MEETINGS

October

10-14—Pacific Area National Meeting, ASTM, San Francisco, Calif.

12-15—Electrochemical Society Corrosion Division, LaSalle Hotel, Chicago, Ill.

17-21—31st National Metal Exposition, Cleveland Public Auditorium, Cleveland, Ohio.

November

7-10—API Annual Meeting, Stevens Hotel, Chicago, Ill.

Canadian Council Joins Inter-Society Committee

National Research Council of Canada has become a member of the Inter-Society Corrosion Committee. Dr. H. P. Godard has been named its representative on the committee.

A committee consisting of Messrs. Frank LaQue, International Nickel Co., New York; Dr. H. M. Trueblood, New York; and Dr. H. H. Uhlig, Massachusetts Institute of Technology, has been appointed to revise the by-laws of the committee.

South Central Region Annual Meeting Held

The annual meeting of South Central Region NACE was held October 3-4 at Dallas. Nine technical papers, a corrosion panel, a fellowship hour and buffet supper and meetings of NACE national organization and technical practices subcommittees were held.

Emphasis of the technical program was on corrosion problems in the petroleum industry and pipe line field, but general corrosion problems were discussed during the panel program.

The Managing Editor of CORROSION magazine always is happy to see photographs considered suitable as subjects for the covers of the magazine. Address such photographs together with descriptive captions and release for use to the Central Office.

Copies of Back Issues of CORROSION Magazine may be secured on request from Central NACE Office, 919 Milam Building, Houston 2, Texas. Some issues have been exhausted and are unavailable. Price is 50 cents per copy for members of the association and 75 cents a copy for non-members.

1950 Conference Local Committees Organized

Six local committees have been set up under Otto Fenner, Monsanto Chemical Co., local arrangements committee chairman for the 1950 NACE Conference in St. Louis April 4-7. He has named the following chairmen and defined the responsibilities of each committee:

Hotel and Meeting Rooms Committee—W. H. Keller, Johns-Manville Sales Corp., 1000 Market St., St Louis, Mo., chairman. Application cards for room reservations will be furnished the association's members from Central Office NACE. Allocation of space in the hotel for each day, beginning with Sunday, April 2, has been made.

Printing Committee—C. E. Mange, Mange Development Laboratory, 4427 Geraldine Ave., St. Louis, Mo., chairman. Principal activity to be in assisting in supplying signs for exhibitors.

Local Publicity Committee—Wm. F. Gross, Tretolite Co., 937 E. Pacific, Webster Groves, Mo., chairman. Will originate and assist in placing publicity locally about conference.

Registration and Information Committee—Andrew T. Pickens, C. K. Williams & Co., 2001 Lynch, East St. Louis, Ill. Will handle tickets for various functions, registration. Limited registration facilities may be made available Sunday afternoon and Monday morning.

Entertainment Committee—E. Ghent Johannes, Mineral Products Co., 2440 Kosciusko, St. Louis, Mo., chairman. Will secure entertainment for social functions. Fellowship Hour and banquet will be held in the Gold Room, Hotel Jefferson.

Ladies' Committee—Mary Ellen Young, Johns-Manville Sales Corp., 1000 Market St., St. Louis, Mo., chairman. Plans are being made for entertainment of 100 ladies. Included are an informal tea, bridge, trips.

Thomas P. May Added To Review Committee

Thomas P. May, International Nickel Co., N. Y., has accepted the invitation of Dr. F. N. Alquist, chairman of the Editorial Review Committee to serve as committee member responsible for handling papers on chemical corrosion intended for publication in Corrosion magazine. Mr. May, who is with the Corrosion Engineering Section, Development and Research Division of INCO, was co-author of a paper "Anodic Behavior of Zinc and Aluminum-Zinc Alloys in Sea Water," a paper included in the Joint Symposium on Cathodic Protection held by NACE and The Electrochemical Society in Pittsburgh, Pa., December, 1947.

NACE NEW MEMBERS and ADDRESS CHANGES

NEW MEMBERS

CONDE, LUIS LOPEZ, Venezuelan Government, Apto. No. 96—Hidrocarburos St., Maracaibo, Venezuela.

CALIFORNIA

LUNDY, DANIEL A., American Potash & Chemical Corp., 3030 West 6th St., Los Angeles 54, Calif.

RADOVICH, FRANK, National Pipe Coatings Inc., 3480 East Randolph St., Huntington Park, Calif.

ILLINOIS

SCRIBNER, LEONARD, Fansteel Metallurgical Corp., North Chicago, Ill.

KANSAS

MITCHELL, JEFFERSON W., The National Cooperative Refinery Assn., McPherson, Kansas.

LOUISIANA

BALL, NORMAN D., Arkansas Louisiana Gas Co., Box 1734, Shreveport, La.

BOURGEOIS, EARLE, Norco Gas & Fuel Co., Inc., Norco, La.

COX, GAYLORD H., 518 No. Pine St., DeRidder, La.

LIVENGOOD, ROBERT G., Johns-Manville Sales Corp., Box 1260, Shreveport, La.

MASSACHUSETTS

CASE, WILLIAM W., H. W. Case Sales Co., Box 838, Springfield, Mass.

MICHIGAN

HIRSHFELD, JAMES F., The Hinchman Corp., 1208 Francis Palms Bldg., Detroit 1, Mich.

NEW YORK

BARNES, FRANK H., The Petterson-Sargent Co., 49-20 Van Dam St., Long Island City, N. Y.

SEARER, JAY C., Durez Plastics & Chemicals, Inc., Walck Road, North Tonawanda, N. Y.

OHIO

FLOCKE, FRANK G., The Thornton Co., 6901 Morgan Ave., Cleveland, Ohio.

HUDOCK, GEORGE W., 1864 Mannering Road Cleveland 12, Ohio.

SEIDMAN, STANLEY M., Ohio Bell Telephone Co., 820 Superior N.W. (Rm. 403) Cleveland 13, Ohio.

SEVERANCE, WESLEY A., The Ceilcote Co., Rockerfeller Bldg., Cleveland, Ohio.

WAGNER, FRANK W., National Tube Co., Lorain Wks., Pearl Ave. & 28th St., Lorain, Ohio.

WARNER, EUGENE C., Akron Sand Blast Co,. 50 E. Springfield Rd., Barberton, Ohio.

OKLAHOMA

CONDRY, JAMES T., Stanolind Pipe Line Co., Box 1979, Tulsa, Okla.

REED, PAUL S., The Oil & Gas Journal, 211 So. Cheyenne Ave., Tulsa, Okla.

ROGERS, JOHN A., Stanolind Oil & Gas Co., Box 591, c/o Purchasing Dept., Tulsa, Okla.

PENNSYLVANIA

BRINK, EDWARD G., Rhoads Lane, R.F.D. #16, Media, Pa.

ROYSTON, THOS. T., Royston Laboratories, Inc., 128 First St., Blawnox, Pa.

RHODE ISLAND

LOEFFLER, WILLIAM J., Nicholson File Co., 23 Acorn St., Providence, R. I.

TEXAS

ALLEN, HENRY W., Cathodic Protection Service, 1801 Bissonnet, Houston, Texas.

DeBORD, GEORGE E., 1318 Wolf St., Galena Park, Texas.

HEITZMAN, EUGENE M., University of Houston Village, T-140, Houston 4, Texas.

HENRY, ERNEST L., The Barrett Divn., Allied Chemical & Dye Corp., M&M Bldg. No. 1 Main St., Houston, Texas.

LOOS, De LASSO, Cool & Stilley Engineering Co., 223 S. Big Spring, Midland, Texas.

SNEDAKER, DELBERT G., 2214 Kipling, Apt. 1-D, Houston 6, Texas.

SPALDING, JAMES C., JR., Sun Oil Company, Box 2880, Dallas, Texas.

VOGEL, ALFRED J., Fuhrman Petroleum Corp., First National Bank Bldg., Midland, Texas.

WADE, PAUL A., 348 W. 23rd St., Houston 8, Texas.

CHANGES OF ADDRESS

(Old Address Follows New Address in Parenthesis)

CALIFORNIA

DUIM, ALBERT R., Mission Appliance Corp., 12611 S. Crenshaw Blvd., Hawthorne, Cal. (12611 S. Crenshaw Blvd., Hyde Park St., Los Angeles, Calif.)

ILLINOIS

RAMIREZ, ING. ERNEST P., Graduate School, Illinois Institute of Technology, Chicago 16, Ill., (c/o Bowers Ltd, S. A., Apartado 976, Monterrey, N. L. Mexico.)

NEBRASKA

WATTS, BRUCE B., K. W. Engineering Co., 231 North 11th St., Lincoln 8, Nebr., (2100 South 56th St., Lincoln, Nebr.)

NEW YORK

HEALEY, EDWARD L., California Texas Oil Co., Ltd., 551 Fifth Ave., New York 17, N. Y., (269 Candee Ave., Sayville, N. Y.)

McCULLOUGH, HAROLD M., Sylvania Electric Products, 149-49 22nd Ave., Flushing, N. Y., (Engineering Experiment Sta., The Ohio State University, Columbus 10, Ohio.)

SHAW, WILLIAM E., National Lead Co., Titanium Alloy Mfg. Div., Box C, Bridge Station, Niagara Falls, N. Y., (National Lead Co. Research Lab., 105 York St., Brooklyn, N. J.)

OHIO

SANDEL, WALTER J., Coatings for Industry, Inc., 1242 Hall Ave., Lakewood 7, Ohio., (2185 East 18th St., Cleveland 15, Ohio.)

SIMS, CHESTER T., 1490 Arlington Ave., Marble Cliff, Columbus 12, Ohio, (Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.)

OKLAHOMA

McNULTY, FRANK E., Pittsburgh Coke & Chemical Co., Rm. 711 Thompson Bldg., Tulsa, Okla., (Koppers Co., Inc., Wailes Dove, Hermiston Dept., 20 E. 5th St., Tulsa, Okla.)

WEST VIRGINIA

HUFF, WILLIAM R., 198 Kenmore, Suncrest, Morgantown, W. Va., (Public Service Co. of Indiana, Box 359, Terre Haute, Ind.)

WISCONSIN

STOCKHAUSEN, FRANK H., 4117 No. Green Bay Ave., Milwaukee 12, Wis., (1937 Falls Ave., Cuyahoga Falls, Ohio.)

TEXAS

AXTELL, OLIVER, Los Fresnos, Texas, (Dept. of Chem. Engrg., University of Maine, Orono, Maine.)

CLAIBORNE, TOM A., Vanadium Corp. of America, 3101 Glen Haven St., Houston 5, Texas, (3816 Marquette St., Houston.)

DAY, STEPHEN D., S. D. Day Company, 2017 West Gray Ave., Houston 19, Texas, (2124 Looscan Lane, Houston 6, Texas).

STEINBERGER, CHESTER, 312 Rusk Bldg., Houston Texas, (P. O. Box 735, Beaumont, Texas.)

WARING, W. H., Johns-Manville Sales Corp., P. O. Box 8217, Houston 4, Texas, (2410 Wentworth St., Houston, Texas.)

NACE MEMBERS

IF You Change Addresses

IF You Change Company Affiliation

IF You Change Positions

Please notify the Central Office NACE, 919 Milam Building, Houston 2, Texas, so that you will get CORROSION without delay and that association records can be kept abreast of your progress.

THANKS!

14 Papers on Corrosion Scheduled at Electrochemical Society Meeting

Fourteen papers on corrosion are to be presented at the yearly corrosion symposium of The Electrochemical Society to be held during its 1949 fall meeting at the LaSalle Hotel, Chicago, October 12-15. The papers are sponsored by the Corrosion Division under the chairmanship of Prof. M. G. Fontana of Ohio State University. There will be three half-day sessions, the first starting Thursday, October 13, at 9:30 a.m. The other sessions will be held Thursday and Friday afternoons. Friday morning is not scheduled in order to make possible attendance at the comprehensive polarography session of the Electro-organic Division.

Following is the complete corrosion program, the papers being grouped so those on inhibition and passivation will be read at the first session, the miscellaneous papers at the second, and those devoted to aluminum corrosion at the third:

Thursday, October 13

A.M.

9:15—Norman Hackerman and E. L. Cook "Effect of Adsorbed Polar Organic Compounds on Activity of Steel in Acid Solutions."

9:45—H. H. Uhlig and Harry C. Gatos "Sodium Metaphosphate as Corrosion Inhibitor for Iron; Effect of Oxygen and Chloride."

10:15—R. B. Mears and R. H. Brown "Part II. A Unified Mechanism of Passivity and Inhibition II."

10:45—Norman Hackerman and J. D. Sudbury "The Effect of Amines on the Electrode Potential of Mild Steel in Tap Water and Acid Solutions."

11:15—Morris Cohen, Rowena Pyke, and Paul Marier "The Effect of Oxygen on Inhibition of Corrosion by Nitrite."

11:45—Recess for lunch.

P.M.

2:00—Thomas P. May and Robert L. Burwell, Jr. "Measurement of the Surface Rougness of Metals."

2:30—W. D. Robertson and H. H. Uhlig "Chemical Properties of the Intermetallic Compounds Mg_2Sn and Mg_3Pb."

3:00—M. T. Simnad "The Electrochemistry of Stressed Metals."

3:30—H. D. Holler "Studies on Galvanic Couples, Part I—Measurement of Electromotive Force and Internal Resistance of Cells During Current Flow. Part II—Some Potential Current Relations in Galvanic Corrosion."

4:10—Walter Beck "Application of an Electrolytic Probe Technique to the Measurement of Corrosion Currents Underground."

4:40—Annual Business Meeting.

Friday, October 14

P.M.

2:00—L. W. Smith and V. J. Pingel "A Micro Solution Potential Measuring Technique."

2:30—Michael A. Streicher "The Dissolution of Aluminum in Sodium Hydroxide Solutions II."

3:00—J. V. Petrocelli "The Electrochemical Behavior of Aluminum."

3:30—M. E. Straumanis and N. Brakss "The Rate of Solution of High Purity Aluminum in Various Bases."

4:00—M. E. Straumanis and N. Brakss "The Effect of Minor Alloying Elements on the Rate of Dissolution of Aluminum in Bases."

The Electro-organic and Electrodeposition divisions of the society also are holding symposia at the Chicago meeting and the Battery Division is holding two round-table discussions. Plant trips scheduled are to the Armour Research Foundation, Lakeside Press of R. R. Donnelley & Sons Co., and the South Works of Carnegie-Illinois Corporation (Electric steel operations). Technical sessions are open to all who register for the meeting. The program booklet gives complete information about the meeting. Secretary of the society is Dr. H. B. Linford, 235 West 102nd Street, New York 25, New York. Chairman of the Chicago Local Committee is C. A. Hampel of the Armour Research Foundation. Hotel reservations should be made directly with the Hotel LaSalle.

ASM Programs Items Of Corrosion Interest

Technical papers to be presented by the American Society for Metals in conjunction with the 31st National Metal Congress and Exposition at Cleveland, Ohio, October 17-21 include the following:

Oxidation Session, M. G. Fontana, Ohio State University, and C. A. Zapffe, Consultant, joint chairmen, October 18. "The High Temperature Oxidation of Manganese," by R. S. Gurnick, Research Engineer, Thompson Products, Inc., and W. M. Baldwin, Jr., Research Professor, Case Institute of Technology. "An X-ray Study of the Scale Formed on Iron Between 400° and 700° C," by O. A. Tesche, Government Metallurgical Lab., University of Witwatersrand, Johannesburg, South Africa.

Seminar on Stress Corrosion in Metals, Wednesday, Oct. 19: "Generalized Theory of Stress Corrosion," by J. T. Waber, Staff Metallurgist, University of California, Los Alamos Scientific Laboratory.

"Corrsion Fatigue and Stress Corrosion as Encountered in a Practical Way in the Petroleum Industry," by M. E. Holmberg, engineer, Phillips Petroleum Co.

"Stress Corrosion Phenomenon Encountered with Stainless Steels and Other High Alloy Materials," by M. A. Scheil, A. O. Smith Corp.

Thursday, Oct. 20—"Stress Corrosion of a Stainless Steel Compressor Through Unbalanced Dynamic Loading and Exposure to a Mildly Corrosive Solution," by Frank W. Davis, Chief Metallurgist, E. B. Badger & Sons Co.

Friday, Oct. 21—"Corrosion Resistance of Molybdenum Bearing Stainless Steel Weld Metals," by R. D. Thomas, Jr., and Anton L. Schaeffler, Arcos Corp.

British Institute to Hold Corrosion Session

Various aspects of corrosion will be discussed at a joint meeting of the Iron and Steel Institute and the British Iron and Steel Research Association at the offices of the Iron and Steel Institute Thursday, October 18, 1949, at 4:00, Grosvenor Gardens, London, S.W. 1.

T. M. Herbert, chairman of the Corrosion Committee of the research association will preside at sessions lasting from 10:30 a.m. to 1:00 p.m. and from 2:00 to 4:30 p.m. Corrosion and corrosion-fatigue of steel will be principal topics.

The discussions scheduled include: "A Simple Form of Accelerated Atmospheric Corrosion Test," by R. St. J. Preston (J. of Iron & Steel Inst. **160,** 286-294 [1948] Nov.); "A Study of the Corrosion Resistance of High-Alloy Steels to an Industrial Atmosphere," by H. T. Shirley and J. E. Truman (J., **160,** 367-375 [1948] Dec.); "The Atmospheric Corrosion of Iron and Steel Wires," by J. C. Hudson (J. **160,** 276-285 [1948] Nov.); "Climatic Effects on the Corrosion of Steel," by J. Dearden (J., **159,** 241-246 [1948] July);

"The Effect of Shot-Peening Upon the Corrosion-Fatigue of a High-Carbon Steel," by A. J. Gould and U. R. Evans (J. **160,** 164-168 [1948] Oct.); "Corrosion-Fatigue of Steel Under Asymetric Stress in Sea Water," by A. J. Gould (J., **161,** 11-16 [1949] Jan.); "High-Speed Rotor Tests of Paints for Under-Water Service," by F. Wormwell, T. J. Nurse and H. C. K. Ison (J., **160,** 247-260 [1948] Nov.); "Electrochemical Studies of Protective Coatings on Metals. Part I—Electrode Potential Measurements on Painted Steel," by F. Wormwell and D. M. Brasher (J. **162,** 129-135 [1949] June).

Separate reprints of the papers listed above are available at 2/6 each from the Secretary of the Institute. Reprints of the following papers at the same price are available also: "The Interpretation of Fouling Samples from Ships," by M. W. H. Bishop, K. A. Pyefinch and Molly F. Spooner (J. **161,** 35-40 [1949] Jan.); "Studies on Anti-Fouling Compositions. Part VI—The Leaching Rate During Early Stages and its Relation to the Surface Condition in Cuprous Oxide Compositions," by H. Barnes (J., **162,** 179-185 [1949] June).

"Celsius" As a name for the scale of temperature more commonly known as "Centigrade" was adopted by the Ninth General Conference on Weights and Measures, October, 1948. NBS points out the change was adopted because of a difference in French in which the official "Centesimale" and Centigrade were involved. It is pointed out that Celsius (abbreviated C) is anologous to the names Kelvin, Fahrenheit, Reamur and Rankine used for other temperature scales. The necessity for choosing between the two terms arises only in French and the decision on a term in the official French language of the conference may not be considered controlling terms used in translating to other tongues.

System of Frequency Monitoring Is Devised

A frequency monitoring system has been devised by R. E. Gould and H. A. Bowman of the National Bureau of Standards Staff for those who use commercial interval timers driven by city power lines for precision measurements. It consists of two motors connected to a differential gear system, one driven by the power line and the other by a standard crystal-controlled frequency. The angular velocity of the differential gear shaft thus depends on the departure of the power line frequency from the standard frequency. Two standard frequencies would hold the gear shaft motionless. Position of the gear shaft at any instant depends on the total integrated frequency error of the power line at that instant.

AICE Program

Symposia including panel discussions on Present Status of Professional Legislation, Corporation Training of Young Engineers, Industrial Waste Disposal, Atomic Energy, Vapor-liquid Equilibria are scheduled to be held December 4-7 during the 1949 annual meeting of the American Institute of Chemical Engineers in Pittsburgh, Pa.

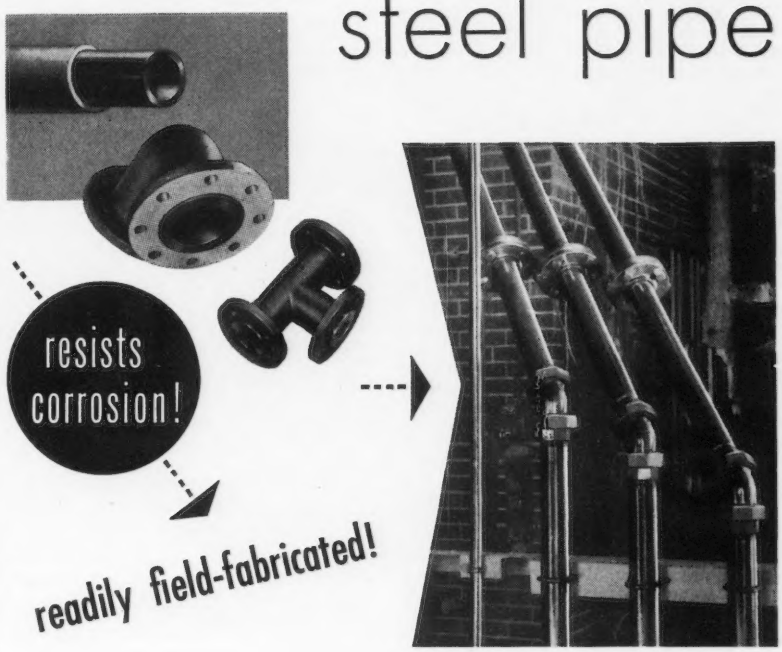
Prof. W. H. McAdams will give the first institute lecture on the general subject of heat transmission.

Plastic Replica Technique

A means of studying surface texture of porcelain-enamel surfaces by a plastic-replica technique has been developed by J. C. Richmond of the Enameled Metals Laboratory of the National Bureau of Standards and A. C. Francisco, research associate of the Porcelain Enamel Institute. Laboratory tests for resistance to abrasion and attack by corrosives usually are designed to reproduce under controlled conditions mechanisms that damage enamel in service. The method permits evaluation of surface texture by either transmitted or reflected light. Specimens may be filed for comparative tests. The procedure is defined in NBS Technical Report 1351.

"**A Study of Paints** for Enclosed Structural Members in Steel Housing Construction," a technical report of a comprehensive investigation carried out at Batelle Memorial Institute under sponsorship of the American Iron and Steel Institute, may be obtained without charge from Lead Industries Association, 420 Lexington Ave., New York 17, N. Y. The report (46 pp., 6 x 9, plus cover) includes tables on paint composition and coating data, coating and blister data for partially immersed panels, weight loss and condition of base metal after stripping panels, rating of various paint systems, coating and blister data for panels exposed to continuous condensation, weight loss from panels exposed to condensation, ratings of paints in condensation test, coating and blister data on panels alternately wet and dry, weight loss from this test, rating from this test, blister data from panels in contact with neutral or alkaline-type insulation in presence of water.

saran lined steel pipe



Saran's unusual resistance to most corrosive chemicals and solvents plays an important part in the reduction of shut-downs and lost production! Saves time and labor! Saran lined steel pipe combines the desirable features of steel pipe—rigidity and strength—with the inherent ability of saran to resist corrosive liquids. Another advantage is its ease of field fabrication—involving *NO* untimely delays with costly handling or special tools. Saran lined steel pipe is available in maximum lengths of 10 feet and in sizes from 1 to 4 inches inclusive. Also available are saran lined plug valves, flanged fittings, union end fittings, flanges, reducing flanges, and gaskets. Write us today for further information concerning saran lined steel pipe and how it may solve your problem. Manufactured by The Dow Chemical Company, distributed nationally by Saran Lined Pipe Company.

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DOW
CHEMICALS INDISPENSABLE TO INDUSTRY AND AGRICULTURE

NEW PRODUCTS—Materials—Service—Literature

Stainless Steel laboratory water stills with sliding joints that can be taken apart without tools are being offered in electric, gas and steam-heated models in capacities from one to four gallons per hour by Precision Scientific Co., 3737 W. Cortland St., Chicago 17, Ill.

Rolled Brass strip material is used in the fabrication of the HPL U Expander designed to maintain proper mechanical pressure on the lip of piston packing in pumps. Supplied in strips of various heights which can be cut to desired size, the material is strongly resistant to corrosion, HPL Manufacturing Co., 2013 East 65th St., Cleveland 13, Ohio, claims.

Durimet 20 Sheet and plate now is available in gauges 24 to 11 and in plates of smaller thickness. The range is from 24 gauge to ¾-inch plate. Durimet is recommended for application in corrosive service where other metals and non-metals prove unsatisfactory, the most notable and widespread use being in the handling of sulfuric acid. Carpenter Steel Company produces bar, strip and tubing of the material. Complete information about the sheet and plate can be obtained from The Durion Co., Inc., Dayton 1, Ohio. Bulletin 502 is a recent publication giving analysis, recommendations for service and a list of applications and other data.

"Stop Corrosion With Metallizing," Bulletin 62 of Metallizing Engineering Co., Inc. 38-14 30th St., Long Island City, N.Y. gives details of the metallizing process in its application in several kinds of corrosive environment. Inquiries about the bulletin or process should be directed to the above address.

"Names of Valve Parts," a bulletin of the Certified Alloy Valve Division of The Cooper Alloy Foundry Co., Hillside 5, N.J. gives diagrammatic sketches of gate, globe, check and lever operated valves along with a uniform material and parts identification code. This is said to be the first publication of this type following the newly proposed standard designations of the Manufacturers Standardization Committee. Copies are available on request.

Industrial Applications Laboratory of The Dow Chemical Company has been moved from Ann Arbor, Mich. to new and larger quarters in Bay City, Mich., Laboratory Director O. C. Cessna, his assistant Edward O. Ohlman and six other key employees also moved. The laboratory now has some 10,000 square feet of floor space.

Nalco Metal, a new lead alloy of National Lead Co., 111 Broadway, New York 6, N. Y., for use in tank linings, anodes and heat exchangers in the chromium plating industry is said to be substantially more resistant to corrosive and pitting action of chromic acid solutions than other lead alloys used for the purpose. It is available in sheet and pipe form.

A New Plastic Diaphragm for Hills-McCanna Saunders Patent Diaphragm valves permits them to handle 66° Be' sulfuric acid without sticking, leaking, or dripping. Sizes from ½-inch through 4-inch with a choice of cast iron, cast steel, Durimet or glass-lined bodies are being offered. Detailed information may be secured from Hills-McCanna Co., 3025 North Western Ave., Chicago 18, Illinois.

A Six-Inch log slide rule of magnesium alloy with a computional accuracy comparable to a 10-inch rule is being offered by Pickett & Eckel, Inc., 1111 South Fremont Ave., Alhambra, Cal. It bears the regular 10-inch log arrangement and sixteen scales including LL1, A-B, T, S, C-D, LL2, LL3, DF-CF, CIF, CI, C-D and L. The combination of C-D scales on both sides, together with folded and reverse scales is a feature of the Model 300.

Technical Paper, submitted in accordance with rules proposed by The Cooper Alloy Foundry Co., Hillside, N. J., will be eligible for cash and prize awards of more than $5000. The present intentions of the company are that the contests cover chemical, food, textile, paper and pulp, aircraft, petroleum, marine and others. The chemical field has been selected as the theme for the first contest. Papers dealing with "Applications for Cast Stainless Steel in the Chemical Industry" will be accepted between October 1, 1949, and May 1, 1950. Prizes, conditions and dates for the other proposed contests will be announced. Complete information about the contest may be secured by writing to the "Contest Editor" at the Cooper Co.

Zinc Bulletin: 6, issued by Zinc Development Association and its members, Spring 1949, Lincoln House, Turl Street, Oxford, England, is devoted principally to the subject "Zinc Alloy Die Castings in Motor Cars."

"Bacco" Process castings are made in molds under thermostatically controlled heat with the molten metal kept under pressure continuously to the point of solidification, according to Budds Aero Castings, Inc., Canaan, Conn. Castings are produced with a much finer granular structure, minimum porosity with tolerances from .001 to .002 of an inch, Harold Budds, president, claims.

"Flume Duct Linings," a bulletin of the Ceilcote Co., Rockefeller Bldg., Cleveland, Ohio, gives information about the company's coatings designed for use in plating, pickling and chemical fume removal systems. Copies are available on request.

"Corrosion Resistance of Stainless, Monel and Nickel Casting," by Norman S. Mott, chief chemist and metallurgist of The Cooper Alloy Foundry Co., Hillside, N. J., a data sheet, is designed to aid engineers in selection of alloys suitable for known corrosive conditions. It is available on request.

Fast Laboratory mixing is claimed for the Brookfield Counter-Rotating Mixer, a product of the Brookfield Engineering Laboratories of Stoughton, Mass. The device uses two motors, and the propellors produce annular rather than circular flow. Materials such as Bakelite powder in solvent, which with conventional mixers require two hours or more for effective dispersion have been thoroughly mixed by the Brookfield device in less than ten minutes, manufacturers claim.

An Installation Manual for use in connection with "Karbate" Pipe and Fittings Booklet, Catalog Sec. M-8800B now is offered by National Carbon Co., Inc., 30 East 42nd St., New York 17, N. Y.

"Gram-atic Balance" a one pan device read directly on a scale at eye level for weighing boiler scale and reagents for boiler water and other tests to 1-20 milligram now is being manufactured by Fisher Scientific Co., Pittsburgh, Pa. All weights are built in and manipulation is by turning four external knobs. No weights are handled and weights less than 0.1 gram are indicated optically and automatically. Beam of the balance has a constant load.

Dedication at Mertztown, Pa., August 20 of the 5000-square-foot Atlas Research Laboratories to the late Maximilian F. Wirtz, who founded the firm in 1892, was featured by the unveiling of a plaque in the founder's memory by his widow, Bernardine Wirtz Dorr. George L. Wirtz, president and son of the founder, in his address related many incidents in the growth of the firm citing among the "firsts" by the company plasticized sulfur compounds, sewer joint compounds, rubber expansion joints, and furan acid and alkali-resistant cements.

The laboratory has a staff of twelve chemists and technicians under the direction of Dr. Raymond B. Seymour, technical director and Joseph Dahle, research director. A modern library with over 2000 technical volumes is available.

Somastic Pipe coating facilities have been made available at a plant on the Intracoastal Canal south of New Orleans, La., by H. C. Price Co., Bartlesville, Okla. The plant, with extensive space for stockpiling bare and coated pipe, can handle all sizes including 30 inches in diameter. It will serve the Southwest through the extensive rail and water transportation facilities available. Robert P. "Bob" White has been named Gulf Division Manager with headquarters at New Orleans. Mr. White, associated with Somastic coating operations since 1940, has been field superintendent in Pennsylvania and New York, administrative manager of the Somastic Division at Bartlesville.

Acid Hose, for discharge, suction and pinch-valve service is described in B. F. Goodrich Co., Akron, Ohio, Catalog Section 3440. The section includes a complete usage table.

yes... an oil seal that's tailor-made to *resist* corrosion

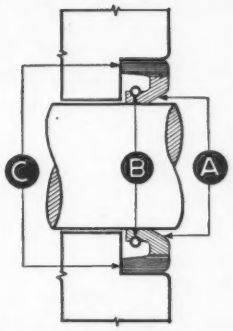
● If corrosive conditions are shortening the life of your oil seals, the Johns-Manville Clipper Seal should provide a practical solution to your problem.

Here's why: The Clipper Seal's molded body is entirely non-metallic and is, therefore, unaffected by most forms of corrosion. To meet special conditions, the garter spring which holds the lip in contact with the shaft can be furnished in various corrosion-resistant metals . . . *or Clipper Seals of special design that do not require garter springs may be used.*

The one-piece, concentric molded design of Clipper Seals also assures a number of other advantages. The hard, tough outer heel of the Clipper Seal is resilient enough to conform even to a slightly out-of-round cavity. And the soft, pliable inner lip always maintains a light, but positive sealing pressure on the shaft, with minimum wear on the seal.

Clipper Seals are quick and easy to install, may be had in split or endless types, are available in sizes from ¼" I.D. up to 66" O.D. If you have a special sealing requirement, or wish to consult about a special design problem, write Johns-Manville, Box 290, New York 16, N. Y.

Here's how *Clipper Seal* works:



The flexible lip (A) is held in light but firm contact with the shaft by means of the garter spring (B). Pressure on shaft is carefully pre-determined to minimize wear, yet effectively seal against leakage. The rigid heel (C) provides a press fit in the cavity, assuring a tight lubricant-retaining seal at this point also.

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NEW PRODUCTS

"Pre-Cementing" through use of H-511 Ubabond, a product of Union Bay State Chemical Co., Cambridge, Mass., can be applied to surfaces which are to be joined together at a later date. The adhesive dries non-tacky in less than 30 minutes and can be be reactivated by heat or solvent spray prior to union with another treated surface. Samples may be secured on request from manufacturer.

A New Threaded metal coupling for use in Pyrex glass pipe lines is being offered by Fischer & Porter Co., Hatboro, Pa. The new coupling is available in ¼, ½, ¾ and 1-inch sizes for making glass-to-glass or glass-to-metal connections.

"The Dresser Bond," a folder describing the new Dresser method of bonding wires for electrical connections between elements of a pipe line, and Installation Instructions, a step-by-step description of the process in which bond wires can be attached quickly without a welding torch, are available on application from Dresser Manufacturing Division, Bradford, Pa.

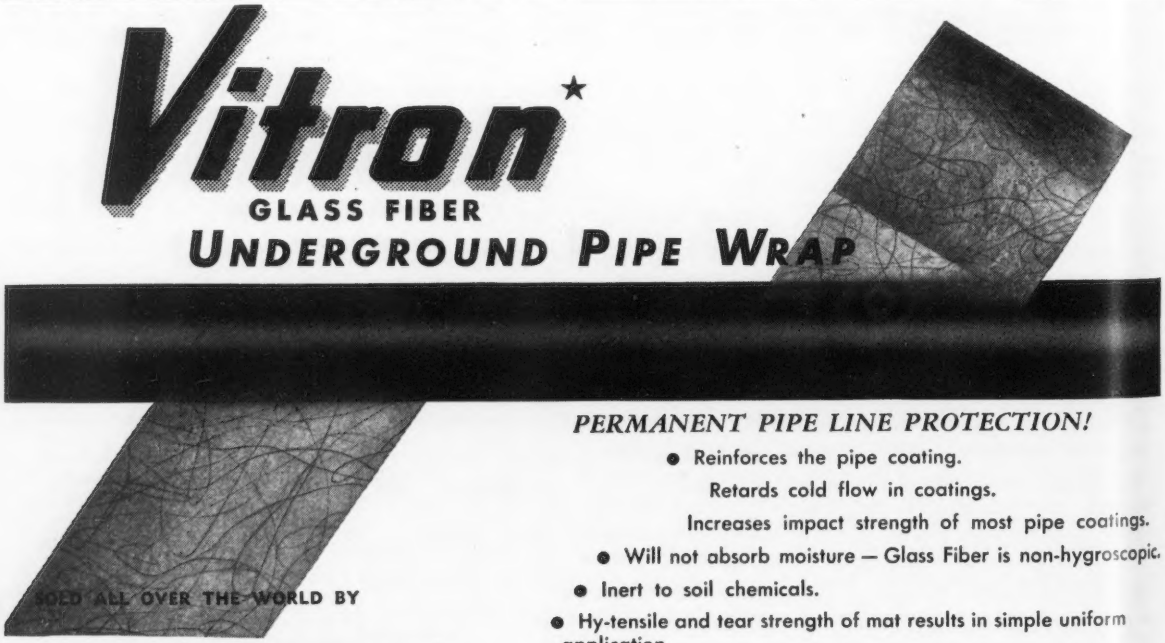
Production of "326" Monel shielded power cable for submarine and underground service is announced in the Driver-Harris Co., in "Alloy Craftsman." The item explains the advantages of the Monel sheathing as corrosion and rust resisting, non-magnetic, easy to solder and light weight.

Alemite "Versatal" pumps, designed to spray viscous liquids even at low temperatures from original drums or containers are being used for many purposes, a folder prepared by the Alemite Company indicates. The folders may be secured from Stone Supply Co., 1320 Polk Ave., Houston, Texas. The literature shows jobs under way, gives specifications and parts lists of various styles of pumps and their capacities. The "Ram" type, for example, can be used to handle heavier grades of mastics, sealers, putties, caulking compounds and many abrasive materials.

Molykote Dry Lubricant, which Alpha Corporation, Greenwich, Conn., claims is composed of a layer of molybdenum atoms with a layer of sulfur atoms on each side is recommended by the manufacturers for bearing pressures on the order of 100,000 pounds per square inch and at either high or low sliding velocities. The technical data sheet issued by the firm states the compound has exceptional chemical stability and inertness and that because "the sulfur in Molykote is chemically combined, the action of the sulfur on some metals is not believed to be the same as that of free sulfur."

Zapon 401-191, low-cost lacquers for use in spray or dip as a coating for wooden toys, chain store household items, novelties and as a coating on pretreated or primed metal is announced by Atlas Powder Co., Wilmington, Del.

Vitron*
GLASS FIBER
UNDERGROUND PIPE WRAP



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- Will not absorb moisture — Glass Fiber is non-hygroscopic.
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RECONDITIONING OPERATIONS

It has been established that the cost of reconditioning an uncoated or poorly coated pipe greatly exceeds the cost of a good initial installation.

However, when replacement is not necessary or feasible, other measures may be used to restore the line to operating condition.

If the pipe is not too badly pitted, spot welding can restore the original wall thickness. In other cases, a half-sole is recommended. Cleaning, re-priming, re-coating and re-wrapping can be counted on to extend the usefulness of the line.

Barrett can furnish coating materials for every kind of reconditioning job. If you have any trouble spots in your pipelines, call on us for help. Our long experience is at your service.

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NEW PRODUCTS

Azed, Inc., 80 East Jackson Blvd., Chicago, Ill., has been formed to engage in the research, manufacture and sale of products and processes for the treatment of zinc surfaces.

"Liquid Stainless Steel," consisting of fine flakes of 18-8 Type 302 stainless steel in a vinyl copolymer vehicle with a volatile thinner is being manufactured by the Lockrey-Fater Corp., 401 Broadway, New York 13, N. Y., and distributed by Slip-On, Inc., of the same address. The manufacturer reports tests by New York Testing Laboratories, Inc., indicating the material is unaffected by 200-hour salt spray test, has high resistance to abrasion, inert to short-time exposure to alcohol, gasoline and 10 percent sodium hydroxide. The report further asserts the coating is unaffected by 5 percent and 50 percent concentrations of sulfuric, hydrochloric, acetic and lactic acids and that 50 percent nitric acid causes a blister. Exposure time is not given.

Pittsburgh Protective Coatings will be handled by S. D. Day Co., Houston, Texas, in the Southwest.

"How to Resurface and Repair Rubber-Lined and Hard Rubber Equipment for Corrosive Service" is the title of Carboline Company's Bulletin C-3, available on request from 7603 Forsyth Blvd., St Louis 5, Mo. The bulletin suggests products and gives step-by-step instructions on repair procedures.

Porce-Lin Tank Lining Co., 456 East Milwaukee Ave., Detroit 2, Mich., is offering a service consisting of installing its "Elastic Porcelain" ceramic lining in hot or cold water tanks. Old tanks first are sandblasted to clean metal, defects repaired by welding, and the lining installed. Indefinite extension of the life of the tank results, the company claims.

New Durco Type A corrosion resisting plug valve embodies the general design of the Durco top-lubricated plug valve made since 1921, but has a composite plug made of a hard corrosion-resistant alloy, such as Duriron or Durichlor. The stainless steel shank is bonded to the plug. The body and gland are made in Durimet 20. Packing for the stuffing box is a combination of corrosion-resistant hard and resilient packing and Teflon anti-friction packing. Complete information is in Bulletin 363 which may be had from The Duriron Co., Inc., Dayton 1, Ohio.

Armour Research Foundation Technology Center, Chicago, Ill., has issued a four-page brochure explaining the activities of the foundation in six sections of applied mechanics research.

CORROSION
costs more today, too!

PIPE LINES of larger diameter, together with increased pumping capacity, make any break in normal operations . . . including breaks due to corrosion . . . far more costly today. That's why it's more important than ever to give your lines the lasting protection of Koppers Bitumastic ® Enamels.

Processed from a highly-refined coal-tar base, Koppers Bitumastic Enamels form a tough, thick barrier between the pipe and such attacking corrosive forces as moisture and soil chemicals. Bitumastic Enamels have high dielectric strength and do not deteriorate with age.

For lower line maintenance expense, specify Koppers Bitumastic Enamels. See your Koppers sales engineer or write for complete information.

KOPPERS COMPANY, INC.
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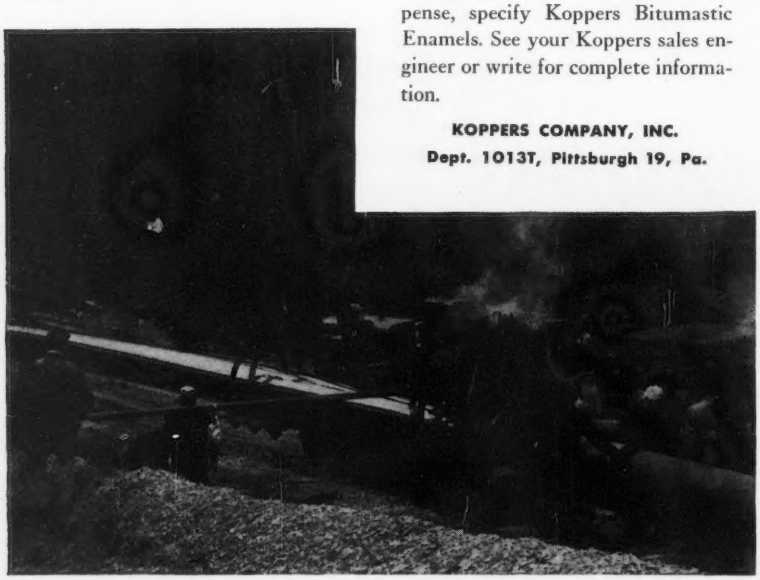

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1. Resists the action of acids, alkalis and other chemicals
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PERSONALS

Philip Heiberger has been named senior lacquer chemist of the Stamford, Conn., branch of Atlas Powder Co., Wilmington, Del.

Richard Baker has been named plant manager for Glass Fibers, Inc., Waterville, Ohio.

W. E. "Easy" Pickens has joined Dearborn Chemical Co., as a service engineer in the pipe line department. He has had wide experience in application of rust preventives to pipe lines. His headquarters will be Chicago.

K. G. Compton, Bell Laboratories, has been named vice-chairman of Metropolitan Section, Electrochemical Society.

A. N. Horne, Tulsa, has been named vice-president and manager of foreign operations for Trans-Arabian Pipe Line Co. He will have headquarters at Beirut, Lebanon.

Van M. Darsey, president, and **Walter R. Cavanagh,** development laboratory manager of Parker Rust Proof Co., Detroit, received the **Sam Tour** award at the annual ASTM meeting at Atlantic City. The award is made yearly to encourage research on the improvement and evaluation of corrosion testing methods and to stimulate technical papers in this field.

D. A. Shock has been named senior research chemist in charge of production chemistry of Continental Oil Company's production laboratory, Ponca City, Okla. Shock has resigned from the research staff of the University of Texas, Austin, where he had been in charge of corrosion research problems, including those sponsored by the Natural Gasoline Association of America. He is well known for his work in condensate well corrosion and is author of several papers on corrosion and allied chemistry problems.

William W. Davis has been named to the electronics division of National Bureau of Standards where he will do research on high-speed electronic digital computing machines.

Philip H. Hardie and **Clarence P. Wilson** have been named principal mechanical engineers with Ebasco Services, Inc., New York. Mr. Hardie, a graduate of Alabama Polytechnic Institute, has had wide experience in power plant design and engineering. Mr. Wilson, a graduate of the University of Arizona, is experienced in power plant and general industrial design.

Dr. J. C. Warner, vice-president of The Electrochemical Society, who presided as chairman of one session of the NACE - Electrochemical Joint Symposium on Cathodic Protection in Pittsburgh, Pa., Dec. 8-10, 1947, has been named president-elect of Carnegie Institute of Technology to succeed Dr. Robert E. Doherty, who will retire next year. Dr. Warner will fill the newly-created office of vice-president of the institute until his inauguration at president.

Frank E. McNulty has been named manager of the Tulsa, Okla., office of Pittsburgh Coke & Chemical Co. He has had wide experience in pipeline construction. **Benjamin H. Means** has been named service manager of protective coatings for the United States. Mr. Means has been active for Pittsburgh Coke in the Houston area for more than a year.

Specialized Industrial coatings developed expressly for corrosion control are described by the United Chromium, Inc., 51 East 42nd St., New York 17, N. Y., in a new bulletin giving essential facts about four groups of coatings for corrosion control, chemical resistance and heavy duty industrial painting. Case histories of applications successfully meeting difficult maintenance problems are given.

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HANDY
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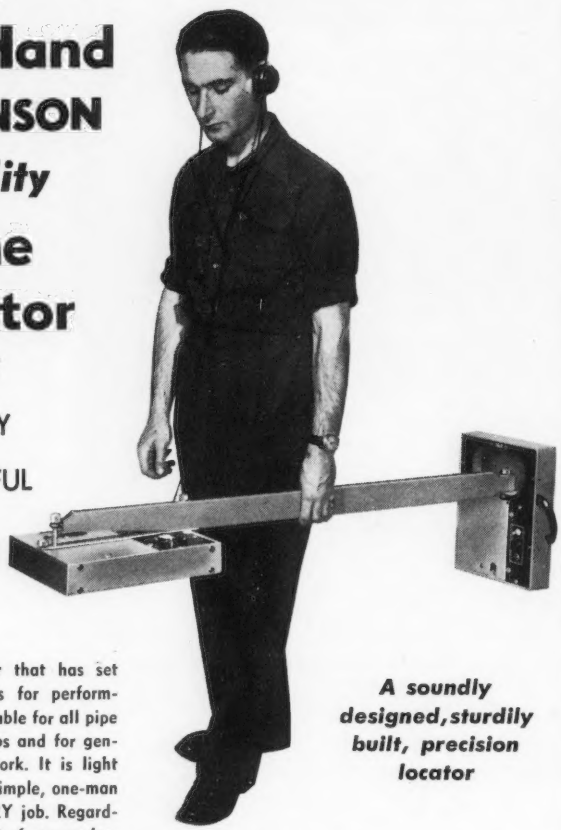

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This is the locator that has set new high standards for performance. It is indispensable for all pipe line construction jobs and for general maintenance work. It is light but powerful—a simple, one-man tool that does EVERY job. Regardless of depth, no part of your underground pipe system can hide from this electronic sleuth. Its skill in detection is unhampered by powerful broadcasting stations or high-tension lines, and it does the sorts of jobs that stymie ordinary devices. Equip with a *proven* professional instrument.

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By Lorraine R. Voigt

Reprinted from Corrosion, 4, No. 10 (1948) Oct.

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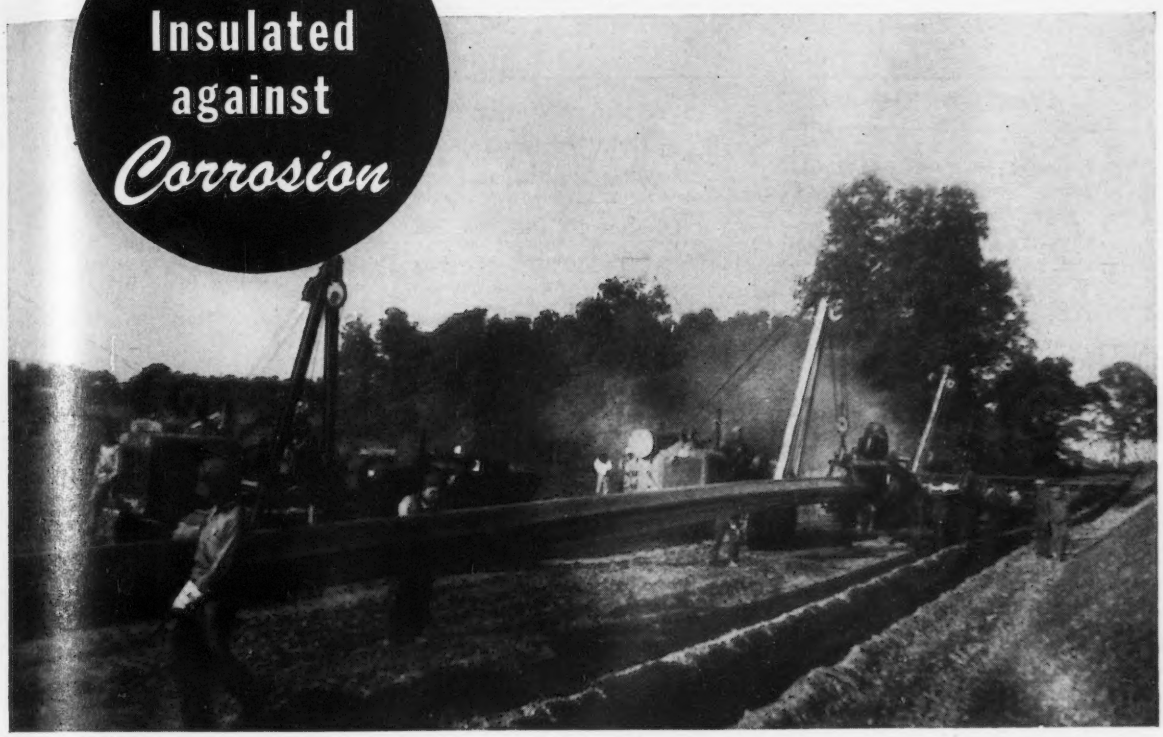

with *Reilly* Pipe Enamel

Reilly Primer and Enamel provide a coating of high dielectric strength that completely insulates the pipe against its environment and prevents all corrosive agencies from coming in contact with the metal.

This Reilly coating is so regulated in its properties that it can withstand temperatures as low as minus 20° F without cracking or checking, and as high as 160° F without flow or sag.

Reilly Enamel is manufactured in two standard grades, also to meet special requirements. It is readily applied—at the mill or in the field—by any of the standard methods.

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Reilly Protective Coatings

A copy of this booklet, describing Reilly Protective Coatings for all types of surfaces, will be sent on request.

Corrosion Abstracts

ATMOSPHERIC

The Importance of Controlled Humidity in Long Time Preservation. G. C. WOLLDS. Amer. Soc. of Naval Engineers, Inc., Prize Essay Content, 1948. *Heating, Piping & Air Conditioning*, **20**, No. 8, 75-80 (1948) Aug.; Disc. No. 9, 105-106, Sept. *Corrosion & Mat. Prot.*, **5**, No. 5, 5-8 (1948) Sept.-Oct. *J. Amer. Soc. of Naval Eng., Inc.*, **60**, No. 2, 127-138 (1948) May.

Maintenance of relative humidity of 30% prevents deterioration from corrosion, mold and mildew, and is practicable of attainment within the envelope of a ship. Description of dehumidification used to effect this, and the preparation of the ship for dehumidification. Practicability to maintain and effectively control humidity aboard ship; cost; necessity of controlling humidity to insure long time preservation and maintaining a relative humidity of 30%, need of preservative coatings as well; probability that O_2 depletion or formation of toxic or explosive gases will make the ships dangerous to enter for necessary inspection; effect of dehumidification on animal life; dehumidification by static means vs. automatic machinery; and destruction of material by the low relative humidity; are discussed. When corrosion is active at the time of dehumidification, at 30% humidity it stops. As time passes, the rust film becomes so dry that the powdery residue may be brushed off.—INCO.

The Corrosion of Metals in Atmospheres Containing Sulfur Dioxide. Part I. G. TOLLY. *Soc. Chem. Ind.*, **67**, 404-407 (1948) Nov.

Results are presented for the corrosion of mild steel, aluminum sprayed, and aluminized steel by air containing from 0.2 to 6% sulfur dioxide at temperatures of 300° to 700°. The influence of gas velocity, temperature and concentration of sulfur dioxide were determined. Corrosion time curves up to 40 hours' exposure are given for 0.2 and 4% sulfur dioxide-air mixtures at 600°. Small concentrations of water vapor in the gas decrease corrosion of mild steel, but further additions increase corrosion. The results show that the catalytic formation of sulfur trioxide on the surface of metals is of great importance in determining the rate of corrosion. The resistance of aluminum coating on steel acts partly by suppressing the corrosive conditions because of the very small rate of catalysis of sulfur dioxide on the surface of the aluminum, and also by resisting oxygen and steam attack.—BLR.

A Study of the Corrosion Resistance of High-Alloy Steels to an Industrial Atmosphere. H. T. SHIRLEY AND J. E. TRUMAN. *J. of the Iron and Steel Inst.*, **160**, 367-375 (1948) Dec.

Tests described were designed to study the effects of composition and surface finish on behavior of the above when exposed for long periods to several industrial atmospheres, without the cleaning treatment normally recommended. The series included some 450 samples, covering 22 steels and 5 nonferrous materials, all in sheet form. The three types of surface finish tested were pickled, emeried, and mirror-polished. Test results are tabulated, illustrated, and discussed. Exposure was for two to five years with vertical specimens and for five years with specimens exposed at 12° to the horizontal.

Abstract Section Style Outlined

For ease in locating reference data, CORROSION uses a uniform style in its Abstract Section.

The abstracts first are broken down into major classifications of the more common types of corrosion literature. In each review the title of the article is presented in bold face type, followed by the author's name. The publication from which the article was abstracted is printed in italics and is abbreviated in most instances. Following this, in sequence, are the volume (bold face), number in the volume, pages, year and month of publication. In some instances a second reference will be listed in the same manner. This indicates that the article also was published or abstracted in another publication. A brief summary of the article follows the above information and it is concluded with an abbreviation indicating the source of the abstract and contributor. The meanings of these abbreviations usually are listed on the first page of the Abstract Section.

When seeking more detailed data about an abstract, best source of information is the publication in which the article appeared originally. (Listed in italics in the heading.) The contributor of the abstract also may be able to supply additional information. Addresses of most of these publications may be found in the reference section of most public libraries.

A Brief Report. Long Time Atmospheric Tests Performed by Swedish Commission of Corrosion. (In French.) EVA PALMAER. *Metaux & Corrosion*, **23**, 285-290 (1948) Dec.

Describes method used and results obtained. Particular emphasis is placed on testing of specimens coated or treated with anti-corrosive agents. Influence of different factors involved is indicated. Data are tabulated.—BLR.

White Zinc "Rust." *Metalloberflache*, **2**, No. 3, 62 (1948).

White zinc "rust," which consists of basic zinc carbonates and is formed on the surface of galvanized, zinc-plated, or Sherardized articles, is caused by the action of moist air on the surface of the zinc. It can be lessened or avoided by: 1) ensuring that the surface is non-porous, 2) storing the articles in dry, airy places with minimum temperature variations, 3) coating the surface with a film of oil, and 4) in the case of galvanized articles, treating the surface with sulphur dioxide as it emerges from the bath.—MA.

BEARING

Light-Alloy Pistons and Bearings. E. MAHLE. *Berg and Huttenmannischer Monatshefte*, Sept., 1948. (In German.) *Light Metals*, **11**, Nos. 129, 130 (1948) Oct., Nov. Condensed English version.

Considers properties and applications. Light alloy bearings are claimed to be characterized by their capacity to withstand high specific loading; by their resistance to deterioration arising from frictional heat; by their good wear resistance, excellent heat conductivity, ease

Abbreviations at the end of abstracts indicate source of abstract and contributor; and are as follows:

AER	*Aeronautical Review*, Institute of Aeronautical Sciences, Inc.
ALL	*The Abstract Bulletin*, Aluminum Laboratories, Ltd.
AWWA	*Journal*, American Water Works Association
BLR	*Battelle Library Review*, Battelle Memorial Institute Library
BNF	*Bulletin;* British Non-Ferrous Research Association
CALCO	Calco Chemical Division, American Cyanamid Corp.
CE	*Chemical Engineering*, McGraw Hill Publishing Co.
CEC	Consolidated Edison Co. of New York, Inc.
EW	*Electrical World*, McGraw Hill Publishing Co.
GPC	General Petroleum Corp. of California
INCO	The International Nickel Co., Inc.
IP	Institute of Petroleum
MA	*Metallurgical Abstracts*, Institute of Metals, London, Eng.
ME	Marine Engineering
MR	*Metals Review*, American Society of Metals
NALCO	National Aluminate Corp.
NBS	National Bureau of Standards
RA	*Refrigeration Abstracts*, American Society of Refrigeration Engineers
RM	*Revue de Matallurgie*, Paris, France
RPI	*Review of Current Literature Relating to the Paint, Colour, Varnish & Allied Industries*, Research Association of British Paint, Colour & Varnish Manufacturers, London.
TDD	*Technical Data Digest*, Air Materiel Command—Technical Service Section
UOP	Universal Oil Products
No Code	*Current Technical Literature*, Bell Telephone Laboratories

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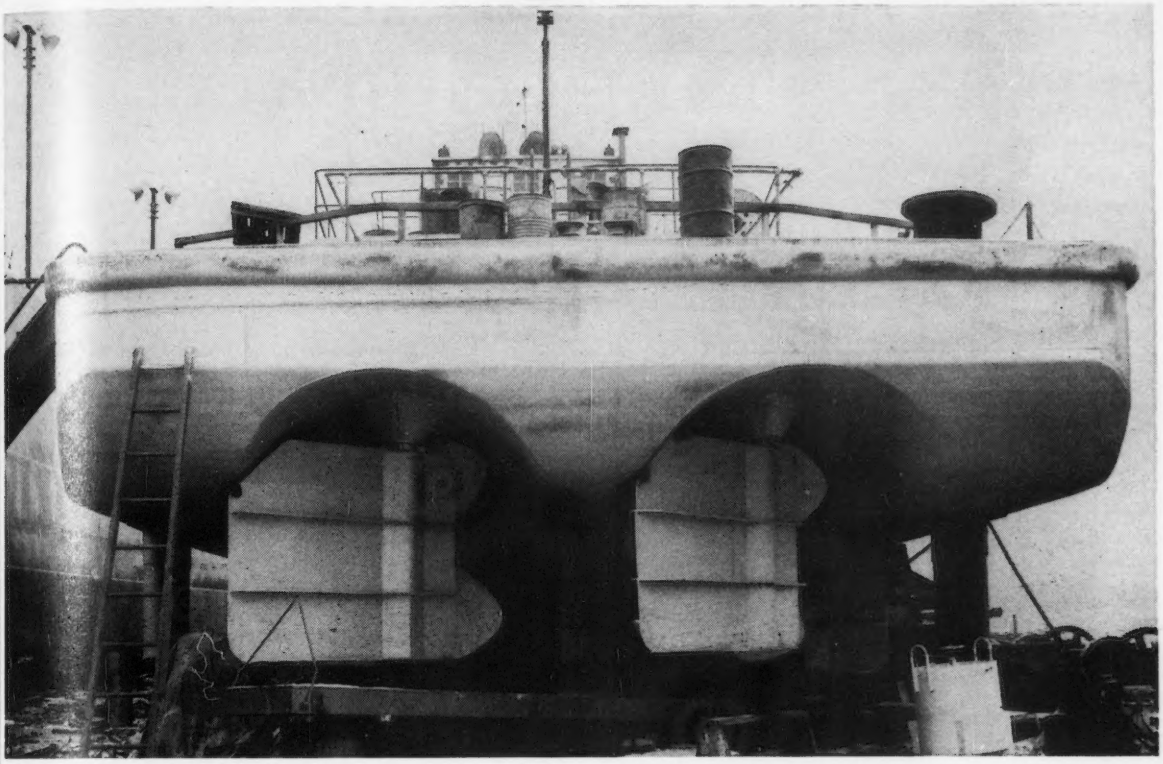

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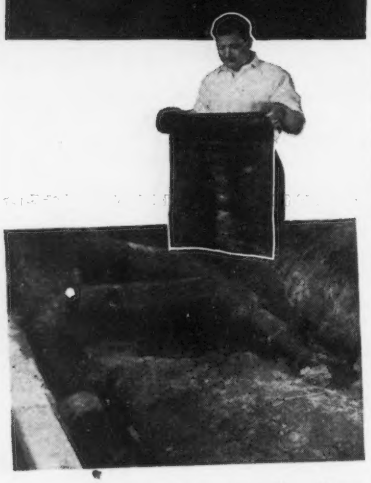

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CATHODIC PROTECTION

Underground Leaks Versus Cathodic Protection. A. SMITH, Dow Chemical Co. *Chem. Eng.*, **55**, No. 11. 139-41 (1948) Nov.

A report of corrosion prevention by cathodic protection of underground structures as started ten years ago at Dow Chemical Co.'s Midland plant is presented. As of December 1, 1947, about 619 anodes (10,000 pounds of magnesium) had been installed on pipelines, and the leak rate had been reduced from 145 leaks in 1943 to 45 in 1946 and 54 in 1947. The installation cost was about $12,400. A new three-way program is now scheduled to get under way soon, consisting of completely protecting one zone in the plant where the most leaks occur, of giving all new pipe lines extra heavy cathodic protection, and of continuing to install anodes at all places where leaks occur, as they occur.

Promote Cathodic Protection to Check Corrosion of Buried Structures. Inter-Industry Correlating Commission on Cathodic Protection. *Petr. Proc.*, **3**, 902-03 (1948) Sept.

A discussion of cathodic protection and methods of its application in checking corrosion of underground structures is presented as prepared by a committee of eight industry associations, two communications companies and an engineering society. The total loss to U. S. industry due to this cause is placed at $1,000,000,000. Estimated mileages of buried structures in U. S. are tabulated.

The Corrosion of Buried or Submerged Pipes. A. H. STUART. *Petroleum*, **11**, 252-253 (1948).

Devoted mainly to steel pipes, but galvanizing is mentioned briefly. Elementary laboratory experiments are described which indicate the value of zinc for use in the cathodic protection of steel pipes. —MA.

Attenuation Equations Applied to Cathodic Protection by Distributed Drainage. E. P. DOREMUS, G. L. DOREMUS, AND M. E. PARKER, JR. *Corrosion*, **5**, 32-36 (1949) Jan.

Attenuation equations have been given which describe variations in current, potential, and cathodic current density along a long uniform structure protected by drainage from a single point. A later paper gave equations for a structure having a finite number of smaller drainage points. Further modification, including consideration of an infinite number of small drainage points, leads to further simplification of the resulting equations. The latter type of installation is employed in the use of magnesium anodes.—BLR.

Corrosion. M. G. FONTANA. *Ind. and Eng. Chem.*, **40**, No. 9, 105A-6A (1948) Sept.

The application of magnesium anodes for the protection of hot water tanks, as investigated and reported by T. E. Larson for the Illinois State Water Survey, is discussed. Aluminum and magnesium, because of low equivalent weights, provide light weight expendable anodes of relatively large diameter and high capacity. Magnesium provides a high potential with respect to iron, and if the water conductivity is not too low and spacing can permit a satisfactory distribution of current density, the use of an impressed current is not needed. Anode efficiencies as high as 55% without and 80% with an impressed current, have been reported for magnesium. Details of the hot water tank installation with magnesium anode are given and a summary of the study is tabulated.

Tests of the Cathodic Protection of Underground Metallic Structures, made by I. A. DENISON AND M. ROMANOFF, NBS.

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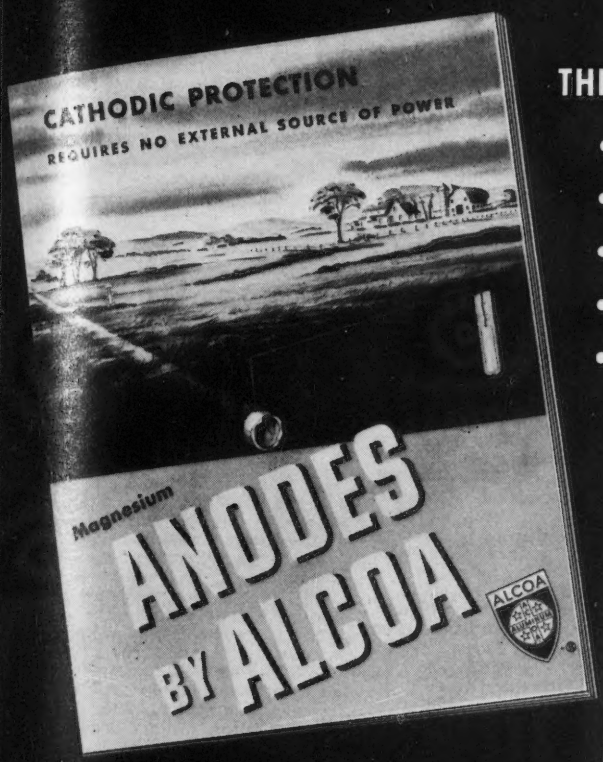

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Heat. & Vent., **45**, No. 8, 122 (1948) Aug.; *Tech. News Bull.*, **32**, 85-6 (1948) July.

The potential difference between local areas on corroded surfaces, which is the cause of corrosion, was eliminated by a supply of energy to eliminate this difference provided by the galvanic corrosion of bars of electronegative metals, zinc, magnesium and aluminum buried at suitable intervals along a pipe line. Protection was provided for as much as six years. Specimens included wrought iron and wrought alloys, cast iron and cast alloys, steel and steel alloys, copper and copper alloys and miscellaneous samples of lead, zinc, metallic and non-metallic-coated pipe, and asbestos-cement pipe.

Cathodic Protection. P. E. HALL. (Hackensack Water Co.) paper before American Waterworks Assn., Atlantic City, May 3-7, 1948. *Eng. News-Record*, **140**, No. 24, 93 (1948) June 10.

Two types of electrical devices used for mitigating corrosion in steel water-storage tanks are conventional cathodic-protection installation, and system employing series of electrical resistances, attached to outside wall of tank. Use of aluminum anode provided with an external potential prevented corrosion of a bare steel surface. Use of galvanic magnesium anode inhibited corrosion of a bare steel surface. Electrode-less circuit showed no protection against corrosion. Dissolved-oxygen concentrations in stored water did not increase when anodes of magnesium or aluminum with an external potential were used.—INCO.

CHEMICAL

Tin in Dairy Equipment. W. R. LEWIS. *J. Soc. Dairy Technol.*, **1**, 27-30; discussion, 30-31 (1947); *Nickel Bull.*, **21**, No. 2, 28 (1948).

Methods used for producing tin coatings are summarized. Consideration is given to the behavior of tinned and tin alloy foils, copper foils, and solder, in contact with dairy products, and reference is made to permissible limits for the tin content of foods.—MA.

Lead-Alloy-Coated Conductors Resist Sulphur Corrosion. *Lead*, **17**, No. 2, 6-7 (1947).

A layer of lead alloy (Okaloy) between the copper and the rubber insulation in cables is found to be extremely beneficial in preventing corrosion in sulphurous atmospheres and from sulphuric acid formed from the sulphur in vulcanized rubber.—MA.

The Anodic Oxidation of Gold in Alkali Hydroxide Solutions. (In English.) F. JIRSA. *Collection of Czechoslovak Chemical Communications*, **13**, 505-513 (1948) Oct.

The mechanism and chemistry of the above were studied experimentally. Data are tabulated and graphed. 14 references.

Use of Monel In Iron and Steel Pickling Equipment. *Iron Age*, **162**, No. 17, 82 (1948) Oct 21.

Discussion of properties of Monel that make it a good metal to use in pickling equipment.—INCO.

Handling Caustics Without Corrosion Problems. (International Nickel Co.) 6 pp. Gratis.

Results are presented of corrosion tests for various metals in refinery use where equipment comes in daily contact with caustic solutions including Monel, nickel, Inconel, 70-30 copper-nickel, 5% nickel steel (SAE 2512), mild steel, and cast iron. Monel was found to be best for almost every type of refinery equipment handling caustics.

The Production of Anhydrous Hydrofluoric Acid; A Study in Anti-Corrosion Technique. *Ind. Chem. and Chem. Mfr.*, **24**, 801-811 (1948) Dec.

Describes and illustrates British plant for the above with emphasis on materials of construction. At acid strengths of 80%, or over mild steel is satisfactory. Below 80%, it is necessary to use plastics in various forms, or non-porous carbon. —BLR.

What To Do About Concrete Deterioration in Food Processing Plants. E. L. HOWARD. *J. Am. Concrete Inst.*, 20 (Proc. **45**), Part 2, 341-343 (1948) Dec.

Gives information on resistance of concrete floors to acetic and lactic acids—as affected by admixes and surface coatings. —BLR.

Galvanic Action Between Lead, Worthite and Other Acid-Resistant Alloys in Sulfuric Acid. W. E. PRATT AND E. T. COLLINSWORTH, JR. *Corrosion*, **5**, No. 2, 39-44 (1949) Feb.

The results are presented of some preliminary investigations to determine the exact mechanism involved in changes of the relative potentials of lead and some stainless steels, notably Worthite in sulfuric acid as an electrolyte. The recorded potential differences between a saturated calomel half-cell and lead, and a saturated calomel half-cell and Worthite were obtained with 50% sulfuric acid at temperatures between 75° and 130° F. It was hypothesized from these experiments that if 50% sulfuric acid was obtained by correct dilution (agitation and heating of dilution controlled so as not to produce a temperature of over 130° F.). Worthite would be cathodic to lead in a galvanic system. The Worthite-lead system was subjected to 66° Be sulfuric acid as it was poured quickly into water to yield 50% deaerated acid with a resulting temperature of 240° F. It is indicated that the theory pertaining to galvanic corrosive action of two metals as being directly related to the difference between them in the galvanic series is not necessarily valid if one of these metals is a high nickel-chrome stainless steel. The controlling factor is the stability of the passive film. A generalized statement can be made, i.e., at higher temperatures of sulfuric acid, lead takes on more noble characteristics, probably due to the lead sulfate film formation, while Worthite and most nickel-chrome alloys become less noble. The point at which Worthite loses its "stable" or practically "passive" state is probably when the temperature reaches a degree where most of the air in the solution is expelled, leaving insufficient oxidizing capacity to repair the broken oxide film. The trouble can be avoided by keeping the alloy in a more passive condition by adding an oxidizing element such as sodium chromate, ferric or copper sulfate, or by reaeration. Where such additions or procedures are not practical or economical, insulating the alloy equipment for metallic contact with lead may be the best solution. Eight illustrations.—TDD.

Bone Fixation and the Corrosion Resistance of Stainless Steels to the Fluids of the Human Body. COLIN G. FINK AND JOSEPH S. SMATKO. *J. Electrochem. Soc.* **94**, 271-277 (1948) Dec.

Bone fixation plates and screws were prepared from three different stainless steels and from one chromium-cobalt alloy. These were tested under conditions closely duplicating those prevailing in the human body. Results showed that stainless steel, such as AISI Type 302, was the most corrosion resistant. Seventeen references.—BLR.

Sulphuric Acid vs. Construction Materials. I, II, III, IV. EDMOND C. FETTE. *Chem. Eng.*, **55**, No. 5, 235-236+; No.

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223-224+; No. 7, 227-228+; No. 8, 219-220+ (1948).

Materials mentioned are (I) rubber linings, cast iron and steel, Worthite, Hastelloy and stainless steel. (II) Precious metals, Durimet and carbon and graphite. (III) F. deals with high-silicon irons, silicones, tantalum, and Haveg. (IV) An account of the properties of chemical stoneware, lead, Chlorimet and nickel and nickel alloys.—MA.

COATINGS

Protection of Aluminum by Coatings of Bichromated Gelatin. (In French.) JEAN FRASCH. *Metaux & Corrosion,* **23,** 261-265 (1948) Nov.

Describes above process, including preparation of solutions and their application. The gelatin contains zinc or manganese bichromate. Also describes corrosion resistance of the coated pieces under severe conditions of various types. —BLR.

Effect of Impurities and Purification of Electroplating Solutions: Some Effects of Copper in Nickel-Plaitng Solutions on the Salt-Spray Resistance of Nickel and Nickel-Chromium Deposits on Steel. D. T. EWING, ROBERT ROMINSKI and WILLIAM KING. *Plating,* **35,** No. 11, 1122-1123 (1948).

A report of results obtained under the American Electroplaters' Society Research Project No. 5. Nickel deposits were made from a Watts-type bath, a cobalt-nickel type bath, and an organic-type bath carefully purified to be free of copper. Deposits of three thicknesses, 0.0003, 0.001, and 0.0015 in. were made from each bath and also from each bath after the addition of 10, 25, 50, 75, and 100 mg/liter of copper. Full details of composition and operating conditions are given. A second set of panels which were subsequently chromium-plated over the nickel were prepared from baths containing 0, 5, 10, 25, and 50 mg/liter of copper. The thickness of chromium was 0.00001-in. for the 0.001 and 0.0015 in nickel coatings, and 0.000005-in. for the 0.0003 in nickel coating. Salt-spray tests on the coatings indicated that copper as an impurity in nickel-plating baths reduces the resistance of nickel-plated steel articles. The effect of the chromium plate over the nickel is to prolong the time in the salt spray, but the same over-all detrimental effect of copper is observed.—MA.

The Grinding and Polishing of the So-Called Soft Metals. RICHARD ERDMANN. *Metalloberflache,* **2,** No. 3, 61-62 (1948).

E. briefly describes recommended treatments for lead and lead alloys, tin, zinc and zinc alloys, and articles which have been cadmium plated, lead coated, tinned by dipping or plating, or galvanized, sprayed, or plated with zinc.—MA.

Zinc Spraying on Menai Strait Suspension Bridge. *Engineering,* **166,** No. 4320, 474 (1948).

The effective resistance to corrosion of zinc-sprayed links is instanced.—MA.

Galvanizing Without Prior Pickling. *Electroplating,* **1,** No. 11, 572-573 (1948).

Brief details are given of a galvanizing process sutiable for cold-rolled or drawn material in continuous form such as wire and continuous strip between 0.2 and 1 mm thick, in which the material is heated (800° C) in an atmosphere of cracked ammonia and immediately passed into a bath of molten zinc-aluminum alloy. A further process for which many advantages are claimed, and which is applicable to all types of material, consists of acid pickling, washing, fluxing in liquid zinc chloride, drying, and hot-dip galvanizing using a zinc-aluminum alloy (420° C). —MA.

Nonmetallic Coatings. JOHN DELMONTE. *Mach. Design.* **21,** 97-102, 162 (1949) Feb.

Discusses engineering characteristics of various types of protective coatings, including organic and porcelain-like finishes. Tables, graphs, and illustrations.—BLR.

Electrodeposited Lead Coatings. G. T. COLEGATE. *Indust. Fin.* (London) 136 (1948) Oct.

The preparation, composition, operating conditions, analysis, and difficulties encountered with lead fluoborate electroplating solutions are reviewed, and brief descriptions given of the use of fluosilicate and perchlorate baths, and an alkaline solution containing litharge and caustic soda, for the electrodeposition of lead coatings. The corrosion-resistance, industrial applications, and recommended thicknesses of electrodeposited lead coatings are also discussed.—MA.

How to Corrosion-Proof Metal Parts. ROBERT G. CLENDENIN. *Steel,* **123,** 85-87+ (1948) Dec. 20.

Reviews various cleaning procedures including removal of such films as mineral and saponifiable oil, insoluble particles, smut, hard water and unrinsed cleaner salts, and oxides. Grease, solvent, oil, and plastic-type corrosion-preventives are also discussed.—BLR.

The Electrolytic Deposition of Tungsten Alloys Containing Iron, Nickel, and Cobalt. ABNER BRENNER, POLLY BURKHEAD, and EMMA SEEGMILLER. Proc. Third Internat. Electrodeposition Conf., 131-146 (1947).

A very detailed account of experiments on the electrodeposition of cobalt-tungsten and nickel-tungsten alloys, with some notes on the deposition of iron-tungsten alloys. Tungsten was co-deposited with the metal of the iron group from an electrolyte containing, in addition to the two metals, a salt of certain hydroxy-organic acids, ammonium compounds, and an excess of ammonia to bring the pH to 8.0 or above. In general, the operating temperature was above 90° C, the pH above 8.5, the cathode c.d. varied from 1 to 30 amp/dm², and the salts of the hydroxy-organic acids were the sodium, potassium, or ammonium salts of tartaric, malic, gluconic, saccharic, citric, and hydroxy-acetic acids. The concentration of the plating-solution constituents varied widely, and a table is included showing the composition of 52 experimental solutions containing sodium, potassium, or ammonium tartrate, citrate, malate, hydroxy-acetate, gluconate, glutamate, lactate or acetate, and the compositions of the cobalt-tungsten alloys produced. The effects of the tungsten/iron-group metal ratio, c.d., temperature, type and concentration of organic salts, concentration of ammonium salts, and pH, together with details of the operation and control of the plating process, are considered in greater detail for the cobalt-tungsten than the nickel-tungsten alloys. Some experimental results covering the following properties of some of the cobalt-tungsten and nickel-tungsten alloys are presented: micro- and crystal structure, hardness, hot hardness, ductility, dimensional change on heating, coefficiency of thermal expansion, density, tensile strength, Young's modulus, fatigue limit, frictional properties, resistivity, magnetic properties, reffectivity, oxygen and carbon content, and resistance to attack by common acids. As deposits several hundredths of an inch in thickness can be produced with good current efficiency, it is considered that the alloys may find industrial application where hardness at elevated temp is required, or for building up worn parts for use in dies.—MA.

Plating on Aluminum. J. G. BEACH. *Met. Rev.,* **21,** No. 12, 5, 7 (1948) Dec.

In recent years applications of aluminum have been increased by plating. Copper or silver plating is used to facilitate soldering, to provide electrical contacts or to increase overall surface conductivity; brass plating permits rubber bonding; chromium decreases frictional wear while copper, nickel, and chromium are used for decoration and protection. Thickness of plate necessary to eliminate porosity on aluminum is generally recognized to be 1.5 mils—comparable to that required on zinc or steel.—ALL.

Studies on Anti-Fouling Compositions —Part V—The Behavior of Mercuric Oxide in Some Anti-Fouling Compositions with Special Reference to the Leaching-Rate Test. H. BARNES. BISRA, Metallurgy Div., Marine Corrosion Sub-Comm., Paper #MG/BC/35/48, June 10, 1948. *J. Iron & Steel Inst.,* **160,** Part 2, 177-184 (1948) Oct.

Discussion of behavior of cuprous oxide and mercuric oxide compositions shows they are different in many respects. Considerable changes in mercuric oxide content with given medium give little change in leaching rate; similar changes in cuprous oxide content with same medium would give rise to different rates. Mercury leaching rate tends to rise, copper leaching rate to fall, in later stages of exposures. For same poison content in same medium, copper and mercury leaching rates are widely different. Loss of mercury indicated by leaching rate determinations is less than actual loss as determined by analysis; in cuprous oxide, reverse is true. The two types of composition differ in physical properties.—INCO.

The Leaching Rate and Behavior of Anti-Fouling Compositions. H. BARNES. *J. of the Oil & Colour Chemists' Assoc.,* 31, 455-461; discussion, 468-470 (1948) Nov.

Discusses limitations of both service and test-stand immersion tests. Both have the disadvantage that no information is obtained on the behavior of the compositions while they are effective. Possible mechanisms and necessary test conditions are discussed. Results of application of a technique described by Harris in 1946 (estimation of the loss of poison under standard conditions from small painted panels) are described, illustrated, and diagrammed.—BLR.

Report of ASTM Committee D-1 on Paint, Varnish, Lacquer, and Related Products. ASTM Preprint No. 57, 1948, 57 pp.

New tentative specifications are proposed for copper powder for use in anti-fouling paint, and for aluminum pigment powders, and paste for paints.—MA.

Lead-Bearing Vitreous Enamel for Aluminum. *Am. Met. Market,* **56,** No. 8, (1948) Jan.

Development of enamels for some

loys of aluminum, to enhance the metal's durability, utility and appearance, has been announced by the Du Pont Company. The new enamel is fired on aluminum strips, sheets and castings in furnaces similar to those used for applying porcelain to steel, but at a temperature several hundred degrees lower. The enamel was developed after six years of research and is ready for large-scale evaluation by the aluminum and enameling industries. At present enamels have been developed for only 61-S wrought and 43 casting alloy. Test panels exposed for two to three years on the roof indicate probable satisfaction for certain other alloys. Because they contain a high percentage of lead the enamels cannot be used for coating articles that are likely to come into contact with food. Tests have shown that the resistance of the enamels to acids and alkalis is comparable to that of enamel on steel. Vitreous enameled aluminum sanitary ware and accessories, washing-machine tubs and agitators, architectural tile, and outdoor furniture are among immediate prospects for evaluation.—ALL.

Prime Coating Aluminum Sheet. CLYDE ST. JOHN *Iron Age*, **163**, 42-45 (1949) Jan. 13.

One solution of the above problem, a wash primer containing a vinyl-butyral resin pigmented with zinc chromate, in use at Permanente Metals Corp., is described; including the technique used for coating sheet and coils. The coating is not disturbed by subsequent light drawing and forming and gives effective protection from corrosion.—BLR.

Metallizing in Relation to Foundry Practice. I. B. STILES. *Foundry Trade J.*, **9**, 85+, (1948) Dec. 2.

Describes protective and reclamatory applications in the foundry, mechanism of the wire spraying pistol, methods of base surface preparation, characteristics of sprayed metal and effect of operating conditions on the hardness of the deposit. Discussion.—BNF.

Organic Finishes for Metal Products. *Steel*, 122, No. 20, 77-82, May 17; No. 22, 56-59+, May 31; No. 24, 96-104, June 14; No. 26, 81-84+, June 28; **123**, No. 2, 97-104, July 12; No. 4, 71-73, July 26; No. 6, 83-93, Aug. 9; No. 8, 77-82, 112, Aug. 23, (1948).

Discussion of practical problem of choosing and applying proper organic coating, gun and electrostatic spray finishing, infra-red baking and metal preparation, methods of cleaning and preparing surfaces prior to painting, and formation of phosphate coatings on steel; important factors in preparation of metal in painting, how to be sure surfaces are clean, methods of getting nonferrous metals set for organic coatings, coating processes include Cronak, Iridite, Anozinc, Lithofirm, and Loxal; selection and classification of organic finishing materials, primer coatings and their applications, resin baking castings by induction heating; properties and applicability of amine-formaldehyde resin coatings, melamine resins, silicone resin, alkyd resin, cellulose base coatings, high solids metal lacquers and other cellulose finishing materials; physical and chemical properties of vinyloid and chlorinated rubber base coatings and some trends in synthetic coatings, such as coating stainless steel during fabrication; testing organic finishes as to salt spray moisture, alkali, stain and grease resistance, hardness and distensibility; abrasion, impact, adhesion and heat resistance testing, electrographic technique for porosity evaluation of protective coatings, and means of effective control over application, processing and handling of finished products. 62 references.—INCO.

Plastic Coatings and Corrosion. C. G. MUNGER, American Pipe & Construction Co. *World Oil*, **128**, No. 9, 176-7, 180 (1949) Jan.

Vinyl chloride and vinyl chloride copolymer groups of resins are considered in the light of their chemical and water-resistant properties and various phenomena of osmosis and electroendosmosis are evaluated in their effects on the success of corrosion-preventive coatings. The studies are of especial value in the protection of tubular goods and tank structures.

High-Temperature Ceramic Coatings for Molybdenum. *Chem. Eng News*, **26**, No. 45, 3362-3363 (1948), and *Brit. Chem. Dig.*, **3**, No. 4, 109 (1949).

Molybdenum with a specially designed ceramic coating may find applications for use at high temperature in oxygen-bearing atmospheres. The coatings are applied as water suspensions and fired at 2150° F (1177° C) in oxygen-free atmospheres. Whereas at 1650° F (899° C) unprotected molybdenum sheet decreased 0.02 inches in thickness in one-half hour, there was no decrease with ceramic-coated molybdenum after 70 hours.—MA.

Anodic Coatings on Magnesium. *Prod. Fin.*, **12**, No. 7, 88+ (1948).—MA.

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Preservation of Hull Bottoms with Lanolin and Beeswax Mixture, Investigation of U. S. Naval Air Material Center, Philadelphia. Report No. AML-NAM-AE 424514. January, 1948.

The properties of lanolin used as a preservative on JRM hull bottoms and the swelling effect produced by a lanolin and beeswax mixture on Buna N washers were investigated. A lanolin - beeswax mixture is recommended on JRM hull areas containing Buna N washers, since it caused only negligible swelling and notably improved the weather resistance of the washers after immersion for 70 hours at 158-160° F. and gave good protection to the washers when exposed to 6-week outdoor weathering.

A mixture of one gallon of lanolin and one pound of beeswax is applied while hot enough to flow. It functions as a protective coating by retarding the action of sunlight and ozone. The Buna N washers are resistant to aromatic fuels and to nearly all other organic fluids within a normal temperature range.—PDA.

Organic Linings for Chemical Equipment. K. Tator, Ind. Lining Engrs., Inc. *Corrosion*, **5**, 55-58 (1949) Feb.

A discussion is presented on organic linings for chemical equipment. Corrosion-resistant metals corrode, but at a rate so slow that service life under corrosive conditions is more than the required life of the equipment or structure in which they are incorporated. Organic linings, however, if properly selected are completely inert to corrosive environment at the time of selection. It is pointed out that to select the proper corrosion-resistant material, one should be familiar with the potentialities and limitations of each chemical group of organic materials used in corrosion work. By utilizing this sort of planned corrosion control it will be found that the most economical and effective corrective systems will be combinations of corrosion-resistant metals, plastics, rubbers, corrosion inhibitors, and/or cathodic devices.—TDD.

Plating and Airlines Efficiency. J. Albin. *Met. Fin.*, **46**, No. 6, 90-94+ (1948) June.

Description of how special plating requirements are performed in an efficient manner on aircraft engine parts. Planned engineering specifications provide key to success in this precision plating set-up. Lead-indium plating is for bearing surfaces subject to high stresses and corrosive effects of lubricants at higher operating temperatures.—INCO.

The Anodizing and Dyeing of Aluminum and Its Alloys. C. C. Hanson. *J. B'ham. Met. Soc.*, **28**, No. 2, 100-127 (1948).

A student paper. H. gives a comprehensive review of information on the theory and practice of anodizing and on the dyeing of anodized surfaces.—MA.

Protective Coverings for Marine Applications—II. Rolt Hammond, *Paint Manuf.*, **18**, No. 4, 129-131 (1948).

Metal spraying by the wire process is described briefly. Sprayed zinc coatings are used in various marine applications. Full-scale experiments on the metallizing with zinc of the hull and decks of fishing vessels and of sea chests, suction strainers, rudder, rudder stock, and rope guards are in progress. Experience in the use of the process for spraying various metals on marine propellers is summarized and a variety of other applications briefly mentioned.—MA.

Adhesion of Enamel Finishes to Electroplating Cadmium Coatings. E. E. Halls, *Metallurgia*, **38**, 75-8 (1948) June; *Austin Tech. News*, No. 249, 3 (1948).

Results are summarized in tabular form of a series of laboratory tests on cadmium-plated steel panels having various types of enamel finish, in which the cadmium was given various chemical treatments prior to enameling. Brief details are given of the tests and the chemical treatments employed.—RCLPI.

An Investigation of the Possibilities of Organic Coatings for the Prevention of Corrosion Fatigue Failures in Steel. R. C. McMaster (Battelle Memorial Inst.) (Paper, 51st Ann. Meet. ASTM, Detroit, 6/21-5/48); abstr. *ASTM Bull.* No. 152, 21 (1948) May.

R. R. Moore rotating beam fatigue tests were made of bare specimens of SAE 1045 steel operating in air and in a corrosive brine and of similar specimens with intact and with scratched organic coatings. The endurance limit of the steel under reversed bending in air in the absence of corrosion was about 48,000 psi. The typical four-layer baked organic coatings increased the operating life in corrosive brines at 40,000 psi fully reversed maximum stress from 430,000 cycles (bare) to more than 64,000,000 cycles (coated). A five-layer system of air-drying materials increased the operating life under the same test conditions to more than 37,000,000 cycles. However, after failure of the organic coating (simulated by scratches cut through the coatings) remaining life-time was found to be about the same as that of new bare specimens. (No more information in abstract.)

Chromizing at 1700° to 1850° F. *Iron Age*, **163**, 65 (1949) Jan. 27.

Describes chromizing process introduced in this country by Diffusion Alloys Corp., New York. The parts to be treated are packed in conventional pack-carburizing containers containing a ferro-chromium base material and a suitable catalytic agent, and heated to 1700° to 1850° F. depending upon carbon content. Preliminary tests indicate promising corrosion resistance, heat resistance, and wear resistance characteristics.—BLR.

Metal Spraying and the Technique Applied to Non-Metallic Materials. *Indust. Fin.* (London) 132-135, (1948) Oct.

A brief general survey of metal-spraying processes and technique, with particular reference to the protection of metal surfaces by sprayed coatings of bitumen, ebonite, polythene, shellac and thiokol. —MA.

Lacquers for the Protection of Food Packs. *Indust. Fin.* (London), 163-169 (1948) Oct.

A description of a range of lacquers for the protection of tinplate food and fruit cans. Recommendations are given on the storage, thinning, application, and stoving of these lacquers, as well as on the pre-treatment of tinplate and aluminum surfaces before lacquering.—MA.

Experience of the Protection of Materials by Pistol-Spraying Aluminum Coatings. M. Haas. *Metall*, No. 3-4, 35 (1948).

H. briefly reviews the applications and corrosion-resisting properties of coatings of aluminum and its alloys sprayed on ferrous and non-ferrous metals.—MA.

Selection and Application of Primer Important in Finishing Aluminum. Allen G. Gray. *Prod. Fin.*, **12**, No. 4, 60 (1948).

The importance of the priming coat in painting on aluminum is emphasized. Zinc chromate pigment is recommended. —MA.

Synthetic Rubber Derivatives as Corrosion-Resistant Materials. Allen G. Gray. *Prod. Fin.*, **12**, No. 7, 86 (1948).

A brief review of the properties and applications of chlorinated rubber.—MA.

Organic Coatings for Corrosion Protection. Allen G. Gray. *Prod. Fin.*, **12**, No. 5, 44+ (1948).

The function of organic coatings in preventing the corrosion of metals is discussed under four headings: 1) the continuity of the coatings, 2) its resistance to the spread of corrosion form uncoated areas, 3) its impermeability, and 4) its resistance to the environment to which it is exposed. The importance of pre-treatment of the metal in preventing under-film corrosion is mentioned.—MA.

Exposure Tests Show Heavier Zinc Coatings Give Longer Life to Steel. *Zinc Bull.*, No. 4, 8-9 (1948).

Discusses recent work on the corrosion of zinc-coated steel by Hudson and Banfield, *J. Iron Steel Inst.*, **154**, p. 229 (1946), and emphasizes the advantages of a thick coating.—MA.

The Protective Value of Zinc Coatings on Steel in Sea Air and in Sea Water. *Zinc Bull.*, No. 5, 8-9 (1948).

A discussion of the merits of galvanizing, zinc spraying, and painting with zinc-bearing paint, for the protection of steel exposed to sea water and marine atmospheres.—MA.

Aluminum-Coated Steel Strip. *Neuhausen Wochenbericht*, No. 28, 5, (1948) Feb. 10. *Mechanique Documentation*, **3**, 2 (Abs.) (1948) May. *J. Iron & Steel Inst.*, **160**, Pt. 2, 229 (1948) Oct.

Two German firms are producing corrosion-resistant aluminum-coated steel strip for covering cables instead of tinplate or galvanized iron, under trade names of Feron and Triwallith.—INCO.

Decorative Finishes for Zinc Alloy Die-Castings. M. P. Willis. *Prod. Fin.* (London) **1**, No. 5, 76-79 (1948).

A survey of chemical immersion treatments for coloring zinc-base die-castings. Some solution formulae are given.—MA.

Porosity of Electrodeposited Metals. III.—Measurement of Intrinsic Porosity. N. Thon and Denis Keleman. *Plating*, 35, No. 9, 917-920, 967 (1948). Cf. *Met. Abs.*, **15**, 419 (1948).

A report on the American Electroplaters' Society Research Project No. 6.

By intrinsic porosity is meant the type of porosity which is present even in "perfect" deposits, i.e. it is not associated with basis-metal imperfections, dirt, etc. It is thought that intrinsic porosity is due to the fine spaces which exist between the crystals of the deposit. Chemical tests do not reveal this type of porosity, at least not fully. A new test is proposed which will detect intrinsic porosity and give a measure of its magnitude. This consists in measuring the rate of flow, at extremely low pressure, of a non-corrosive gas through a plated coating which has been removed from the basis metal. The results obtained indicate that the finer the grain-size of the deposit, the less the

intrinsic porosity. It also is shown that atmospheric corrosion such as that taking place in laboratory air, rapidly increases the intrinsic porosity of thin metal foils. It is concluded, nevertheless, that it is the gross porosity and the corrosion associated with it that determine the service life of an electrodeposit. —MA.

CONSTRUCTION MATERIAL

The Formation of Sigma Phase in Duplex Chromium-Nickel-Molybdenum Corrosion-Resisting Steels. H. W. KIRKBY AND J. I. MORLEY. *J. Iron & Steel Inst.*, **158**, Pt. 3, 289-294 (1948) March.

Results of an investigation of sigma formation in two 18-8 steels containing molybdenum and titanium in the one case and molybdenum and columbium in the other are described. Time - temperature studies showed that sigma forms rapidly at 850° C in both alloys with accompanying increase in hardness, loss of magnetism, and decrease in ductility. Results suggest the formation of sigma causes an alloy depletion locally, which may have an effect on corrosion resistance in certain circumstances. Detailed study was made in regard to changes in microstructure accompanying sigma formation, using etching reagents designed to distinguish sigma from ferrite, austenite, and carbide. Five references.—INCO.

Gas-Turbine Performance. A. HOWARD AND D. O. BUCKLAND, General Electric Co. Paper before ASME, Ann. Mtg., New York, Nov. 29, 1948. *Railway Mech. Engr.*, **123**, No. 2, 55-59 (1949) Feb.

Results of testing 4800-hp GE gas-turbine locomotive unit. An alloy of 16% chromium, 25% nickel, 6% molybdenum, balance iron was found to be a poor material for nozzle partitions at temperatures above 1,500° F, from a corrosion and oxidation standpoint. In an analysis of ash from the turbine nozzles nickel was found in oxide form.—INCO.

Uses for Tantalum and Columbium. T. A. HOOD, Commonwealth of Australia. Department of Munitions. Munitions Supply Lab. Inform. Circ. No. **11**, 1947, 18 pp.

Tantalite ores, frequently containing columbium, long have been mined in Australia, and have been shipped overseas for treatment. Commercial production in Australia is under consideration—hence this review of the properties and uses of the two metals. Tantalum is a platinum-white metal, with mechanical properties similar to those of mild steel, but it can be gas-hardened to about 600 VPN. It can be worked and formed readily. It is chemically inert to many substances, including chlorine and hydrogen chloride up to 150° C, and so finds many applications in chemical plant. It also is widely used in high-power radio tubes, and for electrodes in rectifiers. The carbide finds application in certain grades of cemented carbides. Columbium is a light grey metal, approximating the hardness of wrought iron. It is readily worked, formed, cut, and spot welded. It resists nearly all chemical attack, and readily occludes gases—hence its use as a getter in vacuum tubes. Its major use is as a carbide stabilizer in austenitic stainless steels. A comprehensive classified list of uses is given for both metals, together with a bibliography for the period 1929-1946.—MA.

Observations Concerning the Corrosion of Aluminum Cable With A Galvanized-Steel Core Used for High-Tension Lines After 15 to 30 Years of Service. (In French.) J. HERENGUEL. *Metaux & Corrosion*, **23**, 242-244 (1948) Oct.

Results indicate that life should easily exceed 50 years, without alteration of basic properties.—BLR.

Recent Progress in Corrosion-Resisting Nickel-Base Alloy Castings. M. M. HALLETT. *Nickel Bull.*, **21**, No. 11, 154-156 (1948) Nov.; *Foundry Trade J.*, **86**, 29-31 (1949) Jan. 13.

Reference to the Corrosist series of alloys (D with 10% silicon; boron and carbon with molybdenum) developed by Sheepbridge Stokes Centrifugal Castings Co., Ltd., for resistance to mineral acids. —BNF.

A Zinc Alloy With High Aluminum Content—Part IV. Corrosion Resistance of Wrought Alloys. E. GEBHARDT, *Metallforschung* (Germany), **2**, No. 10 (1947) Oct.

Results are given of the corrosion resistance of the aluminum rich zinc alloy, zinc-aluminum 32-copper 3 in the work-hardened and age-hardened conditions. The usual spray tests were carried out as well as atmospheric exposure tests, total immersion and alternate immersion tests in artificial sea water and stress corrosion tests. In addition to alloys of high commercial purity, samples made from zinc and aluminum of lower quality were tested. For comparison the well known alloys Duralumin, Hydronalium, MS58 brass, zinc-aluminum 14-copper 1 and zinc-copper 4 A were tested.

In the spray test the zinc-aluminum 32-copper 3 produced from low quality metals displayed the highest corrosion rate while the metal of high commercial purity as well as the samples used for comparison evidenced little penetration. Under atmospheric exposure the two rich zinc alloys suffered the most damage with respect to elongation and reduction in area. In this respect the aluminum-rich zinc alloys made from impure metal were most resistant. The change in weight increased, however, with decreasing purity. In the total immersion tests in sea water the two aluminum alloys, Duralumin and Hydronalium showed the most attack judging by impact bending values and outward appearances. The zinc alloy zinc-copper 4 A was also strongly attacked. Zinc-aluminum 4-copper 1 and the samples of zinc-aluminum 32-copper 3 fabricated from impure metal showed the best resistance in this case. The pure alloys showed less resistance. The zinc-aluminum 32-copper 3 alloy of lowest purity evidenced the greatest increase in weight. The results of the alternate immersion tests agreed well with the total immersion results. It also was determined

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that the aluminum-rich zinc alloy had no tendency to stress corrosion.

In the case of zinc-aluminum 32-copper 3, the heat treatment given for hardening proved valuable for raising corrosion resistance. In many cases the improvement was more than 70 percent.

Results of the spray tests do not compare well with the atmospheric exposure, total immersion and alternate immersion tests. The spray tests would approximate results obtained if the alloy were exposed over a lengthy period to a tropical atmosphere.—ALL.

Porous Chrome Hardening of Diesel-Engine Cylinders. C. D. B. WILLIAMS. Diesel Engine Users' Assoc. (Papers), (S. 197) (1948), 3 pp.; and summaries. *Mech. World*, **123,** No. 3185, 118-120 (1948); *Engineering*, **165,** No. 4280. 139 (1948); *Shipbuilder*, **55,** No. 474, 389-391 (1948).

Early attempts to utilize the hardness and corrosion-resistance of electrolytically deposited chromium on cylinder-bore surfaces were very disappointing, and it was not until H. Van der Horst evolved a process whereby a hard chromium surface, covered with minute pits and depressions, suitable for retaining lubricant, was produced, that success was achieved. The main causes of cylinder bore wear appear to be abrasion and corrosion, and chromium is the one material particularly resistant to both these conditions as found in internal-combustion engines. The actual hardness of the bore may be little, if any, higher than that of other cylinder-bore materials, but the corrosion-resistance, high thermal conductivity, and low coefficient of friction are much more suitable than those of other bore materials. Chromium - hardened piston rings must never be used in chromium bores, or seizure is inevitable. The main feature of Van der Horst's method is the production of a surface with the necessary porosity. This may be of two types—channel or pitted—both being produced by a reverse-etch treatment after plating. The average depth of porosity is said to be 0.002-0.004 inch. The necessary equipment is described, and a series of photographs is included. —MA.

Corrosion of Cloth Type Filters. W. O. VEDDER, Pangborn Corp. *Heating, Piping & Air Cond.*, **20,** No. 6, 104 (1948) June.

If dust and conveying air is kept dry and collector temperature is maintained above dew point, corrosive action is reduced. Woolen filter fabric is more acid resistant than cotton. Fabrics woven from manufactured fibers are more acid resistant.—INCO.

Influence of Composition on the Stress-Corrosion Cracking of Some Copper-Base Alloys. D. H. THOMPSON AND A. W. TRACY. *J. of Metals*, **1,** Sec. 3, 100-109 (1949) Feb.

Results presented show that certain high-copper alloys are susceptible to season-cracking or stress-corrosion cracking, and possible explanations are discussed. The work consisted of exposing sheet-metal specimens of copper-base alloys to static tensile stresses of 5000-20,000 psi and simultaneous contact with a continuously renewed atmosphere containing 80% air, 16% ammonia, and 4% water vapor at 35° C. Time-to-failure was the primary measure of results.—BLR.

Properties of Chromium Boride and Sintered Chromium Boride. S. J. SINDEBAND. *J. of Metals*, **1,** Sec. 3, 198-202 (1949) Feb.

It was found that only one chromium boride exists between 12% and 20% boron, instead of two, as previously reported. This compound is said to be chromium-boron structure, unit-cell dimensions, and coordinates of the chromium atom are described. Results of investigation of the pressing and sintering of chromium-boron with a nickel binder, mechanical properties, and high-temperature strength and corrosion resistance are given. Thirteen references.—BLR.

INHIBITORS

The Protective Value of Pickling Inhibitors and its Determination. I. H. FISCHER. *Arch. Metallkunde*, **2,** No. 1, 1-9 (1948) Jan. (In German.)

It has been found that simple laboratory tests on the rate of solution of iron in absence and presence of inhibitors give results which do not always accord with those of large-scale practice. Effect of temperature, of acid concentration, and of iron salts (ferric or ferrous) are discussed.—BNF.

The Dynamic Reconditioning of Corroded (Stored) Aero-Engines. English Electric Co., Napier Technical Publications Dept. *English Electric J.*, **11,** No. 2, 61-66 (1948).

Running the engine for 30 minutes with an inhibitor (Metlgard) from a mobile servicing trolley.—BNF.

Systematic Investigation of Corrosion Inhibition. (In French.) H. C. J. DE DECKER. *Metaux & Corrosion*, **23,** 226-231 (1948) Oct.

Discusses the relationship among concentration of inhibitor, time of contact, composition of material, and nature of medium. Different methods of measurements and interpretation of data are indicated. Includes several graphs.—BLR.

Corrosion Inhibition With Chromate. 1. Introduction and General Data. 2. Drilling—Oil Production—Gas Condensate. 3. Gas Processing Plants and Refineries. 4. Corrosion Problems in Pipe-Line Systems, Tankers, Petroleum Distribution Equipment. MARC DARRIN. *Oil and Gas J.*, **47,** 83+, 87-88+, 85+, 82-83+ (1949) Jan. 13, Jan. 20, Feb. 3, Feb. 16.

Gives extensive fundamental and practical information under each of the above headings.—BLR.

The Action of Organic Inhibitors in the Acid Attack of Mild Steel. T. P. HOAR. Paper, Pittsburgh International Conf. on Surface Reactions (6/7-11/48) Proc., pp. 127-34 (1948).

Weight-loss and single electrode corrosion potential measurements of mild steel corroding in cold and hot 10% w/v sulfuric acid, with and without the addition of a selection of organic inhibitors, were made. In all the experiments in cold acid, and in some hot acids, the corrosion potential is shifted in the "noble" direction by the addition of inhibitor, indicating that the inhibitors have usually a greater influence on the anodic than on the cathodic process in the acid dissolution of mild steel. The widely held view that the inhibition is due to the adsorption of inhibitor on cathodic points only is shown to be based on incorrect reasoning, and recent experiments purporting to support it are shown to favor the hypothesis of general adsorption. Results of present experiments and previous work are discussed from the aspect of monomolecular adsorption following a modified Langmuir isotherm. A new technique for weight-loss corrosion potential measurements in hot acid solutions is described. (Nineteen references.)

Evaluation of Pickling Inhibitors From the Standpoint of Hydrogen Embrittlement. III. Conditions of Cathodic Pickling. (Concluded.) C. A. ZAPFFE AND M. E. HASLEM. *Wire and Wire Prod.*, 23, 1126-1130+ (1948) Dec.

Describes tests conducted under cathodic - pickling conditions. The variable of metal attack is thereby eliminated, the production of hydrogen on the metal surface is controlled, and any polar or ionic constituents of the inhibitor come under the influence of an electric field. Numerous reagents were tested. Most of them increase embrittlement both for mild and stainless steel. A very few inhibit embrittlement for mild steel; none for stainless. Results are shown graphically.—BLR.

Redox Systems as Means of Protection of Metals Against Attack by Water-in-Oil Emulsions. J. REITSTOTTER AND J. RZYMKOWSKI. *Arch. Metallkunde* 2, No. 1, 9-12 (1948) Jan. (In German.)

Water-in-oil emulsions (e.g., water in hydrocarbons) attack iron or aluminum containers. To avoid this oxidizing corrosion it is suggested that organic substances which behave like a reduction-oxidation (Redox) system should be added. After some investigation addition of the organic substance diphenylamine is claimed to be effective (use also suggested for damp gasoline, etc.)—BNF.

A Unified Mechanism of Passivity and Inhibition. R. B. MEARS. *J. of the Electrochem. Soc.*, **95,** 1-10 (1949) Jan.

A mechanism based on the behavior of local elements in metal surfaces is developed. It is suggested that passivity may be achieved either by reduction of open-circuit potential differences between local anodes and cathodes, increased anodic polarization, increased cathodic polarization, or a combination of these factors. Nineteen references.

Pickling Experiments on Zinc and Corroded Galvanized Iron. W. MACHU. *Arch. Metallkunde*, **2,** No. 2, 62-69 (1948).

A study was made of the solubility of: 1) 99.9% zinc, 2) zinc in the presence of iron and 3) corroded, galvanized iron sheets, in dilute mineral acids, mineral acid mixtures, and organic acids, with or without additions of glue (1%), "Rodine" (0.05%), and "Adacid" (0.5%). The acids were at various concentrations, at temperatures of 20° - 60° C and treatment times of 30-60 minutes. The results show that: 1) the presence of iron raises the solution rate of zinc in 5% sulphuric acid by 8 to 10 times at room temperature and 1.4 times at 60° C; inhibitors have no uniform effect on the solution rate. glue has little effect, "Rodine" inhibits at 60° C, while "Adacid" inhibits at room temperature and accelerates at 60° C; 2) a mixture of equal parts of concentrated sulphuric and nitric acids has virtually no action on zinc; iron is passivated in this mixture and therefore does not affect the reaction; 3) organic acids have initially only a slight effect on zinc; inhibitors reduce the attack, iron increases it; 4) zinc is most rapidly attacked by 20% chromic acid at 80° C; 5) zinc is best protected

against acid attack when it has a cathodic connection, and inhibitors are then particularly effective; 6) acid attack on rusted galvanized iron sheets is not affected by the presence of inhibitors nor by cathodic connections; and 7) acetic, oxalic, or phosphoric acid and mixtures of concentrated sulphuric and nitric acids have low rates of attack on the zinc coating of galvanized iron, neither iron nor zinc oxide dissolving appreciably within the times of treatment; it does not appear possible to de-rust corroded galvanized iron without damaging the zinc surface. —MA.

INSPECTION

Ultrasonic Resonance Applied to Non-Destructive Testing. WESLEY S. ERWIN AND GERALD M. RASSWEILER. *R. Sci. Instruments*, 18, No. 10, 750-753 (1947).

A brief general introduction to the method.—MA.

X-Rays in Industry. *Elect. Times*, **114**, No. 2978, 659-662 (1948).

Following a brief review of the history of radiographic testing, an account is given of the methods employed by John Thompson (Wolverhampton) Ltd., for the examination of high-pressure vessels and boiler drums. Illustrations show the radiographic apparatus in place for testing high-pressure steam pipe. Photographic procedures and protection of personnel are briefly discussed.—MA.

Progress of Electronic Inspection. *Chem. Age*, **58**, No. 1488, 115 (1948).

A multi-purpose electronic instrument for sorting metals according to composition or heat-treatment, for measuring plating thickness, and for detecting flaws, etc., is described.—MA.

The Relation of Composition to Stress-Corrosion Cracking in Copper Alloys. MAURICE COOK. Inst. Metals: Symposium on Internal Stresses in Metals and Alloys, 73-84 (1948); discussion, 398-431.

Available evidence indicates that for all practical purposes copper can be regarded as free from liability to stress-corrosion cracking. More information exists about stress-corrosion or season-cracking of copper-zinc alloys than of any other copper-base alloys, and it indicates that although in some circumstances it has been possible to induce cracking in copper alloys of low zinc content, the possibility of failure in service is limited to alloys containing less than 80% copper. The consensus is that alloys containing less than 15% zinc are practically immune from season-cracking. The impurities likely to occur in ordinary commercial brasses do not affect the susceptibility to season-cracking. There is evidence to show that certain elements—including phosphorus, arsenic, antimony, and manganese—may in some circumstances improve the resistance to stress-corrosion cracking, but silicon additions are outstanding in this respect and have a definite beneficial effect, the useful maximum content in 70:30 brass being 1.5%. Other copper-base alloys vary in their susceptibility to stress-corrosion cracking, and evidence relating to the aluminum bronzes, cupro-nickels, silicon bronzes, and nickel silvers is reviewed.—MA.

Properties of Metallic Surfaces. R. M. BURNS. Proceedings of the Pittsburgh International Conference on Surface Reactions, i-viii (1948); *J. Electrochem. Soc.*, **94**, No. 2, 14n-16n (1948).

An introductory paper to the Conference. The properties of metallic surfaces are briefly discussed under the following headings: lubrication and wear, corrosion, oxidation and tarnishing, and catalysis.—MA.

Influence of the Rolling and Annealing Conditions on the Stress Corrosion of Aluminum-Zinc-Magnesium Alloy Sheet. W. BUNGARDT. *Metalloberflache* (Ger.), **2**, No. 7, 137-140 (1948) July.

Work was carried out on aluminum alloy with 4.5% zinc, 3.6% magnesium, in some cases 0.04-0.17% vanadium was added. The effect on the stress-corrosion susceptibility of different hot rolling, intermediate annealing and homogenizing temperatures and of different degrees of final cold rolling was studied. Smaller cold rolling reductions improve resistance to stress corrosion particularly with alloys containing vanadium. The homogenizing temperature is important and the presence of vanadium enables a higher temperature to be used without causing susceptibility.—ALL.

Resistance to Sensitization of Austenitic Chromium-Nickel Steels of 0.03% Maximum Carbon Content. W. O. BINDER, C. M. BROWN AND R. FRANKS. ASM Preprint No. 25, 48 p. (1948) Oct.

An investigation on susceptibility to intergranular corrosion.—BNF.

Internal Stresses and the Formation of Hair-Line Cracks in Steel. J. H. ANDREW AND HSUN LEE. Inst. Metals: Symposium on Internal Stresses in Metals and Alloys, 265-273 (1948); discussion, 432-462.

The formation of hair-line cracks in steel is discussed and explained on the basis of internal pressures caused by hydrogen. It is suggested that molecular hydrogen can be accommodated at the mosaic disjunctions or boundaries, and that the variation in the size of the mosaic blocks may account for the different ways in which steels of different compositions and treatments react to hair-line crack formation. Other sources of internal stresses in steel are discussed briefly, and certain well-known metallurgical phenomena are interpreted in the light of the manifestation of such stresses.—MA.

METAL FAILURE

Graphitization of Welds in Steam-Pipes Made of Molybdenum Mild Steel. F. MEUNIER. *Revue Soudure*, **2**, 51-71 (1947); *Brit. Abst.*, BI, 206 (1948) May.

Breakdown of welded joints in high-pressure pipelines after several years of use was found to be due to a change in the structure of the metal immediately surrounding the seam caused by separation of the carbon of the steel in the form of irregular chains of graphite. Causes of this graphitization were investigated by studying the change of mechanical properties and structure with time of heating at temperature between 300 and 1200°. Presence in steel of manganese, chromium, vanadium and molybdenum delays breakdown of the joint, while silicon, aluminum, titanium, copper and nickel accelerate graphitization. Curative and preventive measures are

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suggested, including heat treatment to redissolve the graphite. Photomicrographs of various steels and the change which occurs on graphitization are included.—INCO.

Corrosion of Magnesium (and Its Alloys). W. S. LOOSE. *Metals Handbook,* Amer. Soc. Metals, 994-999 (1948).

L. describes the corrosion of magnesium in various atmospheres, aqueous media, and soils. Galvanic corrosion and corrosion at high temperature are also dealt with.—MA.

Chemical Manifestations of Internal Stress. F. H. KEATING. Inst. Metals: Symposium on Internal Stresses in Metals and Alloys, 311-331 (1948); discussion 463-484.

The combined effect of internal stress and a corrosive environment is discussed in a general way, and the significance of this combination—generally referred to as stress-corrosion cracking is indicated. The literature on stress-corrosion cracking of the commoner industrial alloys is briefly reviewed, and some examples of such cracking in industrial plant are recorded. The various factors involved in stress-corrosion cracking are considered, and a tentative explanation of the mechanism of such cracking is proposed.—MA.

Thermogalvanic Effects in Corrosion. P. L. GILBERT. *Metal Treatment,* **15,** No. 53, 31-32 (1948) Spring; discussion, 32.

Temperature theories of corrosion, namely, temperature effects, thermogalvanic corrosion importance and the corrosion of copper, silver, zinc, iron, aluminum and magnesium by temperature are discussed. 2 references.—INCO.

Stress-Corrosion Cracking in Alloy-Steel Gas Cylinders. R. C. GIFKINS AND W. P. REES. *Metal Treatment,* **15,** No. 55, 109-122, 131 (1948) Autumn.

It is shown that quenched and tempered nickel-chromium-molybdenum steels will crack if stressed below the yield point (e.g. 10 ton/sq. in.) in the presence of hydrogen sulphide, water vapor and air. Carbon bisulphide and hydrogen cyanide in the presence of water and air can also cause stress corrosion cracking, though the time for cracking is longer than with hydrogen sulphide. Includes numerous tables, photographs, and photomicrographs.—BNF.

A Zinc-Base Alloy of High Aluminium Content. IV.—Corrosion Properties of the Forged Alloy. ERICH GEBHARDT. *Metallforschung,* **2,** No. 10, 310-320 (1947); *Met. & Met. Abstracts,* **15,** 407 (1948).

A study was made of the corrosion-resistance of the zinc-base alloy containing aluminium 32 and copper 3% in both the as-forged and the forged and age-hardened conditions, in contact with artificial sea water. The results are compared with those of similar tests on Duralumin, Hydronalium, brass, and zinc-base alloys containing copper 4% or aluminium 4% and copper 1%. A comparison of various testing methods, such as weathering, complete or alternate immersion in artificial sea water, stress-corrosion, and subjection to water vapor at 95° C. for periods of up to 28 days, showed that the last-mentioned test gives the most sharply defined results, although they are unrelated to those obtained by the other methods. Warm ageing of the forged material leads to a 70% increase in corrosion-resisting properties. It is concluded that the alloy is suitable for use for long periods in tropical climates. Results showed that, in general, the alloys made from pure metals have the highest resistance to stress corrosion.

Age-Hardening. MARIE L. V. GAYLER. Inst. Metals: Symposium on Internal Stresses in Metals and Alloys, 255-264 (1948); discussion, 432-462.

A brief resume is given of the theories of age-hardening which have been put forward during the past 26 years. Recent metallographic analyses have led to the deduction that highly localized stresses are formed within the lattice during the process of age-hardening, on a submicroscopic as well as a microscopic scale. The existence of such microscopic stresses is also indicated by X-ray diffraction photograms. The development during age-hardening of such stresses at highly localized points within the lattice must have a profound effect on the behaviour of the alloys when subjected to different tests, and particular emphasis is laid on the importance of this fact in relation to stress-corrosion and creep tests.—MA.

The Resistance of Nickel and Nickel Alloys to Corrosion. W. Z. FRIEND. *Metals Handbook,* Amer. Soc. Metals, 1041-1044 (1948).

An account is given of the resistance of nickel, nickel-copper alloys, nickel-molybdenum-base alloys (Hastelloys), nickel-chromium alloys, and nickel-chromium-copper-molybdenum alloy (Illium) to various atmospheres, waters, salt solutions, mineral acids, organic acids and compounds, alkalies, and dry and wet gases.—MA.

The Relation of Composition to Stress-Corrosion Cracking in Copper Alloys. MAURICE COOK. Inst. Metals: Symposium on Internal Stresses in Metals and Alloys, 73-84 (1948); discussion, 398-431.

Available evidence indicates that for all practical purposes copper can be regarded as free from liability to stress-corrosion cracking. More information exists about stress-corrosion or season-cracking of copper-zinc alloys than of any other copper-base.

Causes and Prevention of Drill Pipe and Tool Joint Troubles. Part IV. Drill Pipe. Part V. Tool Joints. H. G. Texter, R. S. Grant, and S. C. Moore. *World Oil,* **128,** 90, discussion 102, 104 (1949) Jan.; 96-97 + (1949) Feb. 1.

Part IV deals with troubles due to worn pipe, crooked pipe, collapsed pipe, eccentric-wall pipe, internal erosion, and magnetism. Gives recommendations for minimizing difficulties. Part V describes and illustrates various types of mechanical difficulties with tube joints, such as longitudinal splitting, galled or frozen threads, and wabble failures. 17 references. (To be concluded.)—BLR.

REFINERY

Field-Erected Storage Tanks of Aluminum. F. L. Plummer, Hammond Iron Works. Paper before AWS, Ann. Mtg., Philadelphia, week of October 24, 1948, *Welding J.,* **27,** No. 10, 796-804 (1948) Oct.

Discussion of aluminum alloys and their properties, aluminum in chemical and process tanks, and aluminum in petroleum storage tanks. Aluminum tanks are economical for use with "sour" crudes. In tanks constructed of aluminum and steel, galvanic action can be prevented by use of thin strips of synthetic rubber coated with suitable adhesive, neoprene without adhesive inserted between plates and caulking compounds.

Processing Sour Crudes at Globe, Lemont Refinery. R. B. Pierce, W. G. Krause, and J. M. Lawson. Paper before Western Petrol. Refiners Assn., Lansing, Aug. 27, 1948. *Petrol. Processing,* **3,** No. 10, 941, 944 (1948) Oct.

High percentage of organic chlorides in Wyoming stock was found to cause severe corrosion through formation of hydrogen chloride in Globe's Perco bauxite catalytic desulfurization unit. Corrosion occurs in upper section of fractionation and in overhead condensers on topping unit. Metals involved are both carbon steel and admiralty alloy. Hydrogen blisters are blisters on outside walls of tanks and vessels. Theory of this is that hydrogen sulfide in fluid within tank reacts with metal to produce hydrogen which in turn diffuses outwardly with formation of bubbles. Danger from H_2S is less when unit is shut down with sweet crude in system. Globe uses a Garbitol amine unit to remove H_2S.

Oil Industry Corrosion. *Oil & Gas J.,* **47,** No. 21, 152+ (1948) Sept. 23.

Corrosion problems connected with oil production, refining and pipe lines are covered in the following papers presented at the South Central Regional Meeting of the N.A.C.E., Tulsa, (Sept. 20-21, 1948): (1) "Crude Still Overhead System Corrosion," by A. F. Blumer (Esso S. O. Co.) described the corrosion problems encountered in operations of the company's Baton Rouge, La., refinery; (2) "Steam Reboiler Corrosion," by W. S. Janssen (Pan American Refining Corp.) related some of the experiences obtained in combatting corrosion in equipment operating in alkylation service at Texas City, Texas; (3) "The Microscope as an Aid in Solving Corrosion Problems," by H. M. Wilten (The Texas Co.) described the use of the microscope in corrosion problems; (4) "The Mitigation of Corrosion on City Gas-Distribution Systems," by A. D. Simpson, Jr. (United Gas Corp.) described the steps taken to protect from high corrosion rates sections of the gas-distribution system operated by United Gas Corp.; (5) "The Value of Backfill with Carbon and Graphite Anodes," by J. P. Oliver pointed out that these materials divert much of the electrochemical attack from the ground rod and that the graphite anode is more resistant to electrochemical attack than is the carbon anode; (6) "Electrolysis Experiences on 115 kv. High-Pressure Oil-Filled Pipe-Type Cable Installation in New Orleans," by S. E. Trouard (New Orleans Public Service Co.) related experiences with corrosion of an 11-mile, oil-filled pipe line for electrical power transmission; and (7) "Preliminary Examination of Acid and Alkali Resistant Coatings." W. R. Smith discussed the factors to be considered in selection of coatings.

SURFACE PREPARATION

Pre-treatment of Galvanized Iron Prior to Painting. *Indust. Finishing (Lond.),* **1,** 247-248 (1948) Nov.

A very general survey of recommended mechanical and chemical treatments for galvanized surfaces prior to painting.—MA.

The Oxygen Efficiency in Anodic Oxidation of Aluminum. John Kronsbein. *J. Electrochem Soc.*, **94**, No. 6, 353-366 (1948).

Experiments are described which show that the view that anodic oxide coatings on aluminum grow inwardly because of slow chemical solubility of the oxide, is not the correct one. The concept of "oxygen efficiency" is put forward. This is the fraction of the electric current passed through an anodizing cell that is used in the formation of the oxide coating, the remainder being used to generate free oxygen or else in anodic dissolution of the aluminum. Simple mathematical expressions are derived which relate c.d., temp. of electrolyte, and concentration of electrolyte with this efficiency. It is also shown that, taking into consideration the solubility of the oxide in the electrolyte, the coating grows to a maximum thickness. A relationship is shown to exist between the abrasion resistance of the coating and the oxygen efficiency.—MA.

Surface Active Agents in Non-Ferrous Metals Technology. J. Koerner. *Metal Ind.*, **73**, No. 23, 452-453 (1948).

K. discusses the theory underlying the action of wetting agents and describes their application in non-ferrous metallurgy.—MA.

The Surface Treatment of Aluminium and Its Alloys by Anodic Oxidation. S. T. M. Johnstone. Australia. Council for Scientific and Industrial Research, Division of Aeronautics, *Report SM. 116*, Aug., 1948, 23 pp. (Obtainable from Aeronautical Laboratory, Fisherman's Bend, Melbourne.)

A review of present theory and practice. Principles and mechanism of anodic oxidation; various anodic treatment processes; properties of anodic films, including color, thickness, absorption, hardness, abrasion resistance, corrosion resistance and some physical properties; sealing and dyeing treatments; applications. 32 references.—BNF.

Proper Rinsing Following Alkali Cleaning Operations Is Important. Allen G. Gray. *Products Finishing*, **12**, No. 7, 82 (1948).

The importance of thorough rinsing is stressed, and the need for an adequate volume of wash water and a sufficiently long drainage time is pointed out. Spray rinsing is mentioned briefly.—MA.

Barrel Finishing of Aircraft Parts. Joseph Wingate. *Metal Finishing*, **46**, No. 10, 67-74 (1948).

Very good results can be obtained on a wide range of articles by careful observation of established principles and making thorough and accurate tests. The need for a system of recording and compiling data for future runs is emphasized. An unlined steel barrel running on a horizontal axis can handle a wide variety of parts made of aluminium, brass, magnesium, copper, bronze, and all grades of ferrous metal. The abrasive medium should be of 300-600 mesh grit bonded ceramically or chemically with a filler approximately as hard as the medium itself, it should be processed to ensure even, consistent wear on all surfaces, and it should resist splintering and chipping during use. Suggestions are put forward for media evaluation tests, and recommendations are made on abrasive sizes, the use of soaps and detergents, work loads, barrel speeds, precleaning for barrel operations, and loading barrels.—MA.

Shot Peening for Longer Life. L. J. Wieschhaus. *Modern Machine Shop*, **21**, No. 4, 112-130 (1948).

W. discusses briefly fatigue strength and its improvement by shot peening of steels and aluminum alloys. Shot-peening methods and machines are dealt with.—MA.

Surface Treatment and Finishing of Light Metals, Part I. S. Wernick and R. Pinner, *Sheet Metal Industries*, **25**, No. 260, 2463-2470, 2484 (1948) Dec.

This is the first installment of a series of articles on light metal finishing. The development, advantages, uses, corrosion resistance and finishes for the different classes of alloys are discussed in turn. Tables are included giving the compositions of the principal wrought and cast aluminium alloys.—ALL.

Ferrous and Non-Ferrous Pickling. I. Industrial Hazards and Diseases Encountered. II. Health Precautions and First Aid. Hermine Vogel. *Metalloberflache*, **2**, No. 4, 87-90 (1948); No. 7, 150-152.

Extracts from the second edition of "Handbuch der Metallbeizerei," by Otto Vogel. V. describes the dangers encountered and the precautions necessary when pickling or treating metals with mineral acids, chromic acid, alkalis, cyanides, and organic solvents.—MA.

Polishing Precious Metals. H. K. Stegeman. *Metals Handbook* (Amer. Soc. Metals), **1948**, 1109.

Methods of lapping, buqing, brushing, rouge and color buffing, "butler" finishing, and scratch brushing are given.
—MA.

Pickling, Etching, Pre-treatment, Derusting and Protective Treatments. Parts II and III. R. Springer. *Metalloberflache*, **2**, Nos. 9, 10, 199-203, 224-229 (1948) Sept., Oct. In progress. (In German.)

First part was noted *B.N.F. Bulletin* **231**, 287 (1948) Sept. Second and third parts survey literature and patents on inhibitors (continued); electrolytic pickling and descaling; and chemical, electrolytic and "mechanical" etching.—BNF.

Surface Cleaning in Molten Salt Baths. *Metalloberflache*, **2**, No. 3, 63 (1948).

The author briefly describes the operation and applications of: (1) molten caustic baths, working at 360°-540° C., with or without electrolysis, and (2) molten metallic sodium baths, working at 375° C., under atmospheres of hydrogen or cracked ammonia from which all traces of oxygen, carbon monoxide, and carbon dioxide have been removed.—MA.

The Present Position Regarding Chemical Pretreatments for Magnesium Alloys. S. E. Mayer. *Magnesium Review and Abstracts*, **8**, **29-45** (1948) Jan.

Reviews treatments and classifies them according to the chemistry of the film formed. Discusses the principal types, giving bath compositions. Considers possibilities of future developments. Tabulates the various proprietary methods in seven groups with information on inventor, alternative designation, literature or patent reference, bath compositions, method of application, alloys for which suitable, purpose of treatment, general description, pretreatment necessary, and special comments.—BLR.

Methods and Types of Cleaners for Various Metals. *Materials & Methods*, **29**, 89, 91 (1949) Jan.

A tabular presentation.

Mechanical Finishing with Roto-Finish Techniques. Arthur P. Schulze. *Plating*, **35**, No. 9, 911-916 (1948).

Tumbling operations using wet mixtures of specially developed chips and compounds are described. The processes are highly flexible and can be applied to parts weighing from a fraction of an ounce up to 75 pounds each. Stampings, forgings, extrusions, machined parts, or die-castings can all be treated. The methods are suitable for ferrous and non-ferrous metals. Four basic types of operation are carried out: (1) grinding and deburring, (2) polishing, (3) bright honing, and (4) coloring. Examples are given on costs and the time required for various operations. Deburring is carried out in an octagonal-shaped wood-lined barrel, using specially sized and prepared mineral chips and special compounds, the nature of which is not stated. Polishing and bright honing are similar operations, but use less-abrasive bright-honing chips. In the coloring operation steel balls are used instead of mineral chips.—MA.

INDEX TO ADVERTISERS

OCTOBER, 1949

Vol. 5 **No. 10**

	Page
Allied Chemical & Dye Corp., Barrett Division	9
Aluminum Co. of America	17
American Brass Company	vii
American Hot-Dip Galvanizers' Assoc.	25
Bechtel Corp. & H. C. Price	vi
Cathodic Protection Service	23
Cathodic Servicing Co.	ix
Corrosion Engineering Co.	8
Crose, M. J., Mfg. Co.	8
Dearborn Chemical Co.	Inside Front Cover
Dowell, Inc.	ii
Dow Chemical Co. (Saran Lined Pipe Co.)	5
Duriron Co., The	Inside Back Cover
Electro Rust-Proofing Co.	16
General Paint, (Hill, Hubbell Co. Div.)	28
Huddleston Engineering Co.	23
Johns-Manville Co.	7
Koppers Co., Inc.	10
Mayes Bros., Inc.	i
Middle West Coating & Supply	21
Midwestern Engine & Equip. Co.	x
Minnesota Mining & Mfg. Co.	15
National Carbon Co.	11
Owens-Corning Fiberglas Co.	19
Perrault Bros.	viii
Pittman, Wm. G.	10
Plastic Lining Corp.	18
Reilly Tar & Chemical Co.	13
Rosson-Richards Co.	23
Sims, C. I.	23
Standard Pipeprotection, Inc.	v
Stearns, D. E.	Back Cover
Tapecoat Co., The	16
Tator, Kenneth	23
Thayer, Starr	23
Wilkinson Products Co.	12

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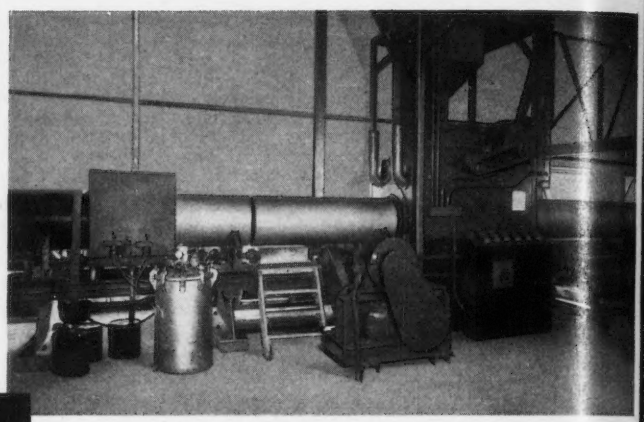

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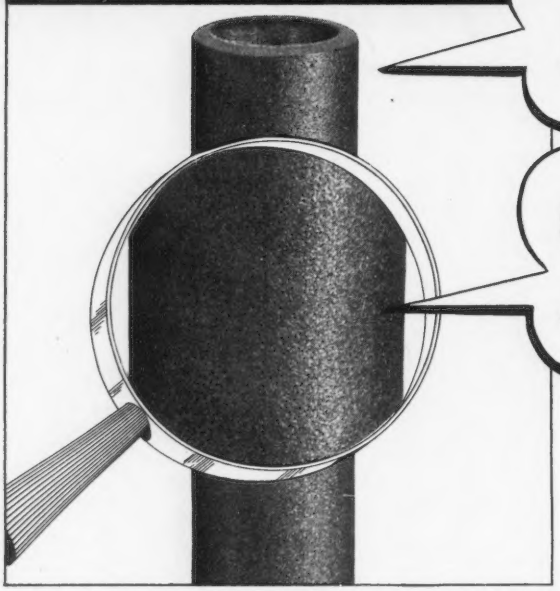

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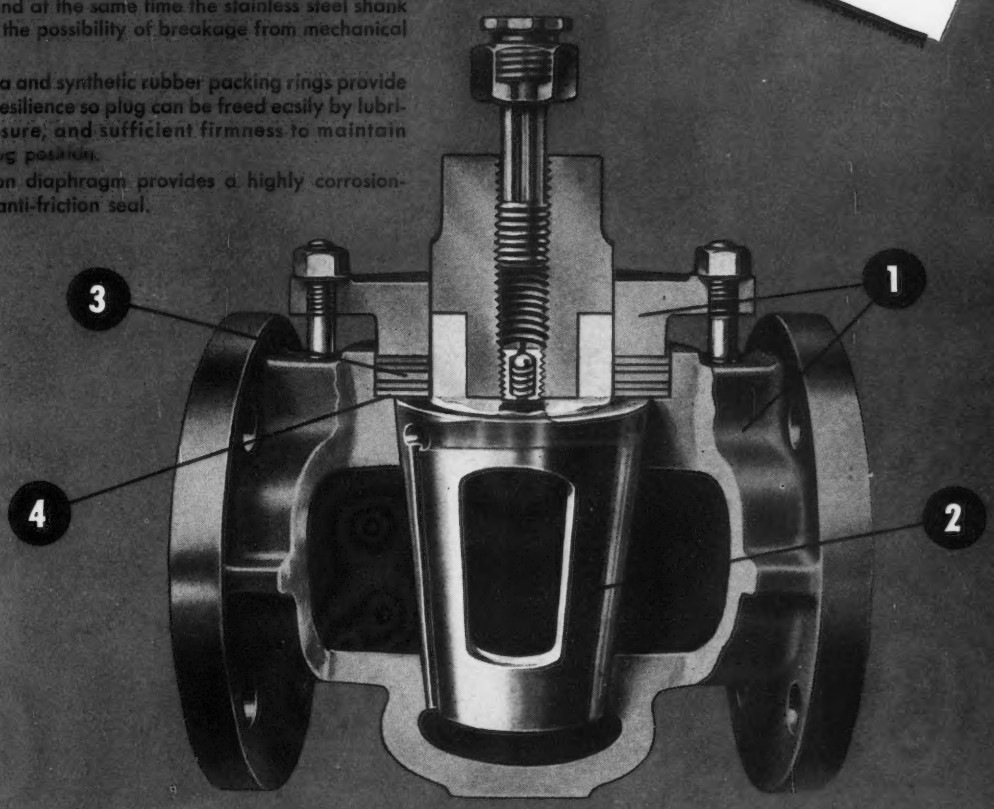
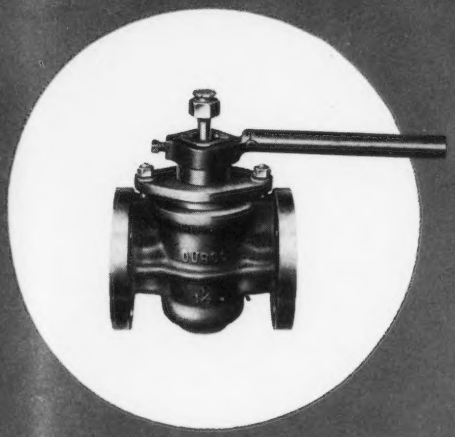
4. A Teflon diaphragm provides a highly corrosion-resistant, anti-friction seal.





The DURCO Type A is a top lubricated plug valve for general chemical service at pressures up to 150 lbs.

The mechanical design, as well as the composition of the alloys used in the construction of this valve, are the result of 37 years of intensive corrosion research. Special tooling and quantity manufacture make it possible to offer this valve at a very attractive price.

Available sizes: 1", 1½", 2" and 3". Delivery of valves with Durimet 20 bodies and composite plugs from stock.

Write for a copy of Bulletin 636. Or, if you prefer, a DURCO engineer will be glad to discuss valve problems with you, at any time.

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